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Vol. xx AUGUST, 1915. No. 8

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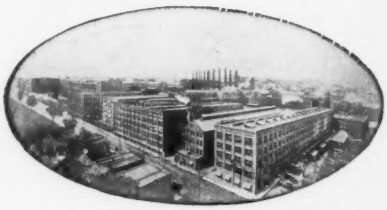

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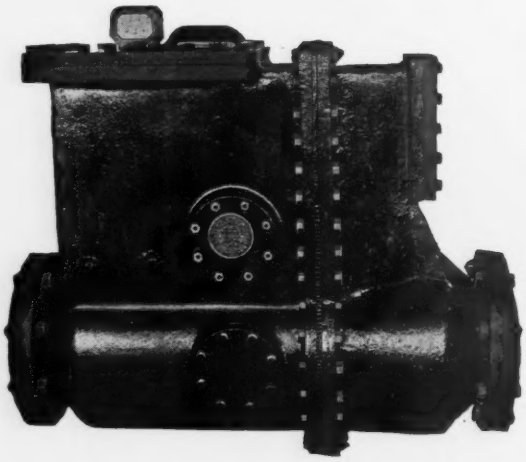

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COMPRESSED AIR MAGAZINE

EVERYTHING PNEUMATIC.

Vol. XX AUGUST, 1915 No. 8

METAL SPRAY PROCESSES*

BY JOHN CALDER.

It is the object of this paper to describe the latest mechanical process, the Schoop process, for depositing electro-positive metals on iron and steel. Incidentally, the method permits the depositing of many other metals and alloys on coherent bodies whether metallic or not.

The process takes its name from M. U. Schoop, an engineer, of Zurich, who, in collaboration with other inventors, made the metal spray an effective coating agent. In the Schoop process, the coating metal adheres to the object chiefly by mechanical union. The metal is discharged in hot impalpable particles moving with high velocity and these when directed upon a prepared object penetrate the pores of the latter while the spray is still plastic. The coating metal thus dovetails itself into the superficial pores of the object and does so in the presence of reducing gas which prevents oxidation at the junction of the metals.

The progress of invention on metal spraying has been chiefly directed toward making the metallic particles as small and as hot as possible, thereby avoiding oxidation, and reducing the pressure of air used and the cost of the gases employed.

The evolution of the apparatus has been interesting. The liquid metal process involved a large non-portable reservoir of hot metal weighing with the auxiliary parts over a ton; the metal dust apparatus weighed over a hundred pounds, while the "pistol" of today weighs less than four pounds. Figs. 1, 2 and 3 show the three forms through which the apparatus has passed.

In the apparatus represented by Fig. 1, a molten metal is allowed to run continuously from the reservoir *R* through a broad nozzle *N*, where it is broken up and swept away by a violent current of heated gas *G*, issuing under regulated pressure from containers *C* and reheated in its passage at *H*. The expansion of the gas chills the molten particles and forms a rapidly moving spray or fog of metal which impacts upon any object placed in its path and plates it.

Any metal fusible under the conditions of the apparatus can be used and owing to the low temperature of the fog, it is possible to plate very delicate and easily combustible objects, as well as metal articles. Aluminum plating, which could not be obtained by fusion or electrolysis on account of its ready oxidation, was easily obtained by this Schoop process.

The obvious objections to such an apparatus were lack of portability and the expense of melting and keeping fluid most of the metals in the unavoidable intervals of spraying. The result was that only the more fusible metals, lead and tin, were used where spraying on a continuous scale was possible and the liquid metal apparatus was never reduced to economical practice. It was observed with this apparatus, however, that the particles were not actually molten at the moment of impact and this suggested the next step.

Fig. 2 represents the second form of apparatus in which portability was secured and the metal particles to be sprayed were prepared in advance. Powdered metals in a very fine state of division have many of the characteristics of a liquid. Their fine particles mix with one an-

*Abstract of paper before the American Society of Mechanical Engineers, May 11, 1915.

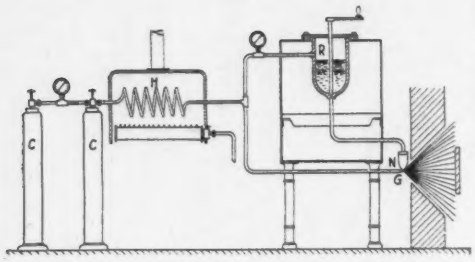


FIG. 1.

other like drops, they spread with facility and unite under the influence of very little force. The metal powder in the container *C* is entranied in an air blast *A*, heated in the flame of a blast pipe *B*, and projected with high velocity. The gas is burned at *D* and the supply of air is regulated at *S* to obtain complete combustion.

It was found that the anticipations from the use of the first apparatus were correct and that metal particles projected in a pasty condition produced plating as before. Most metal powders, however, tend to oxidize rapidly and the use of this apparatus was practically restricted to tin and zinc on this account. Even with tin, the expense of metallic powder was prohibitive, but the plating with tin and zinc was very good. In the case of zinc, the apparatus known as the cyclone is still the most economical instrument for plating large surfaces with that particular protective metal. Zinc dust is a by-product in the stacks of zinc smelteries. With the Cyclone apparatus, it can be impacted on steel structures either in the field or at the factory.

Inventors then set themselves to overcome both the chemical and economic difficulties, viz.: to dispense with mass melting and dust preparation and to secure instant and simultaneous operation of melting and pulverization, and control with a handy, economical and easily transportable appliance. The result was the ingenious instrument known as the "pistol" which is shown in Fig. 3.

The principle involved consists, as shown in Fig. 4, in feeding a fine wire *W* of any metal into a reducing flame zone *Z* at such a constant speed that the position of the end of the wire *E* remains stationary, the melting rate being exactly equal to the rate of feed. Under such conditions the wire end melts a drop at a time and each drop at the instant of formation is struck a violent blow by an air blast *A*. In other words, the pistol is a machine gun which automatically manufactures its ammunition from a reel of wire and bombards the object to be plated with plastic projectiles of extremely small size.

The resulting fog or spray of fine metallic particles into which the drops are divided takes the form of a diverging cone *C* with a core of reducing gas *G* in which the particles are entrained, and a surrounding sheath of air *A* which is rapidly expanding and cooling. Any suitably prepared object placed in the path of this metallic spray is plated through impact without undue elevation of temperature.

Fig. 6 shows a section of the commercial spraying pistol now in use. The principal parts of the pistol consist of an outer casing *A*, cast of aluminum, with a central projecting tube forming a handle, a wire feed mechanism mounted entirely upon the cover *B* of the turbine chamber, the turbine *C* actuating the wire feed mechanism, gas, air and wire nozzles mounted upon the outer casing held in position by a hand nut *D*, and a re-

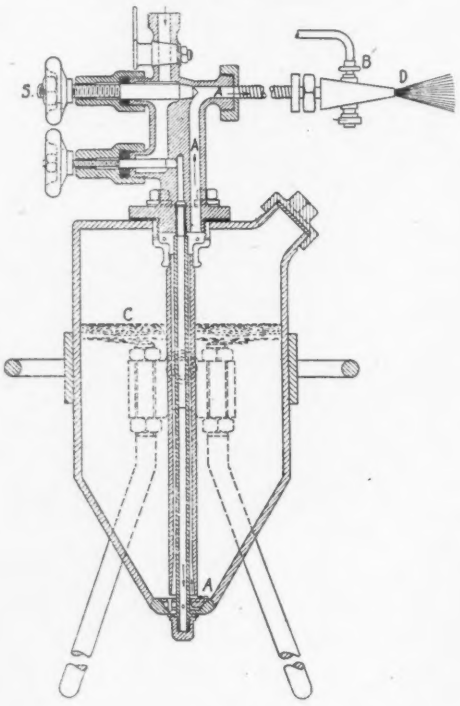


FIG. 2.

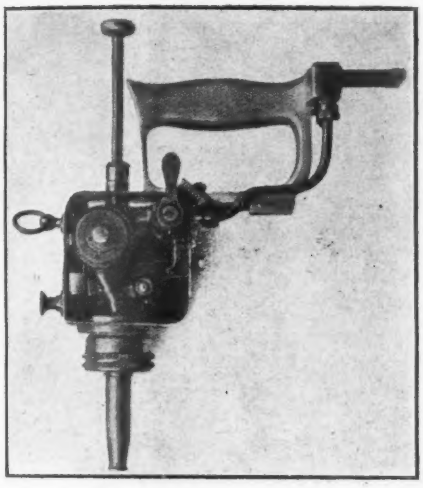


FIG. 3.

movable cover *E* which completes the enclosure of the outer casing.

Gas and air ducts are drilled in the outer casing. The flow is controlled by the tapered valve *F* provided with a handle *G*. The wire feed mechanism is actuated by a turbine *C* mounted on a vertical shaft running in ball bearings; a worm is cut in the upper end of the vertical shaft and drives by worm wheels the horizontal shafts *N* and *O*, Fig. 6, which are provided with worms in turn driving the worm wheels *P* and *Q*.

The wheels *P* and *Q*, Fig. 6, are provided with slots to engage the projecting lugs of the lower feed wheel *R*. The upper feed wheel *S* mounted in the pivoted frame *T* is provided with shrouds controlling the position of the lower feed wheel *R*. The lower feed wheel can be engaged in either worm *P* or *Q* by raising a clip *I*, shifting laterally in either direction and locked in by the opposite clip. The shift can be readily made by allowing the mechanism to run slowly by a slight opening of the starting valve.

Pressure is applied to the feed wheels through the pivoted frame *T* by a coiled spring, and controlled by the operator by means of the release lever *K*. The final adjustment of the wire feed is controlled by the needle valve *M*, Fig. 6. The turbine and shaft complete is assembled in the outer case and properly adjusted independently of the other mechanism.

The wire feed is entirely assembled on the turbine cover *D* and, when properly adjusted is secured in position. The wire nozzle base *U* provides an adjustment for position of wire and gas nozzles, and is secured in position by a headless set screw. The upper end of the stem of the turbine cover is provided with an annular groove, which is engaged by the spring loop *V* and secures the removable cover *E* of the case. Loop *V* provides also a means for hanging the pistol on a conveniently located hook.

The operation of the pistol is as follows: The gas and blast nozzles faces *B* and *C* are securely clamped to form gas tight joints by tightening the hand nut *D*. The end of the central or wire nozzle is then 0.015 in. inside the gas nozzle and the stationary melting point of the wire is 0.03 in. inside the air blast nozzle. The wire diameter used is from 0.0319 to 0.0375 in., except for lead and tin which are used in larger sizes owing to their rapidity of melting.

The feed gears having been set in mesh at the approximate speed required for the wire selected, the air alone is turned on and the speed tested with a short length of wire. Adjustment, if necessary, is made by the needle valve which modifies the speed 2 ft. per minute plus or minus.

The end of the wire reel is then threaded through the stock receiving tube, between the gripping feed rolls and into the central wire nozzle and the fuel gas pressures from the containers are adjusted by the reducing valves and gauges thereon to the tabular requirements for the metal to be sprayed. The pressures of the fuel gases seldom rise above one atmosphere and hydrogen or Blau gas are the reducing gases usually employed. This gas is now admitted by slightly opening the starting valve and when ignited with a match burns quietly as a pilot light.

The starting valve is then opened up full and oxygen is admitted gradually until the flame zone is established. All back-firing is avoided by keeping the reducing gas always in excess of the oxygen, the ratio being three

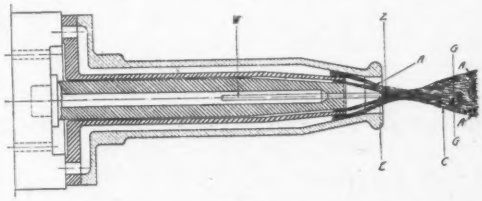


FIG. 4.

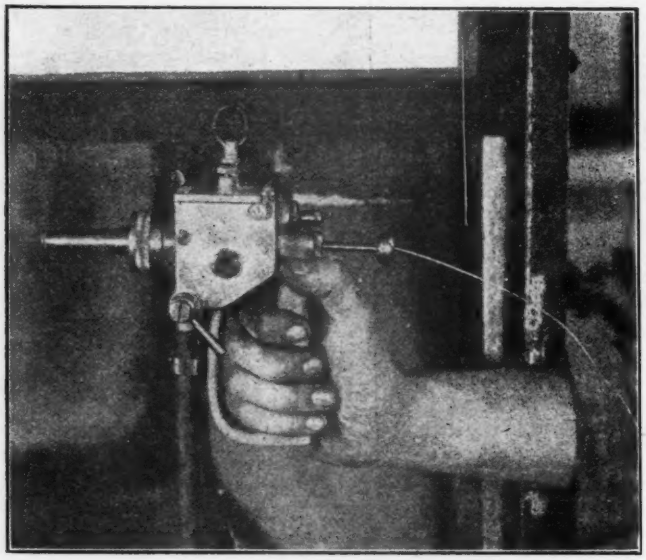


FIG. 5.

or four to one. The above movements are made in rapid succession on a light instrument which can be held in one hand and the spray is started up the moment the constant melting position of the wire is reached.

The spray so established is essentially a metal plating air-brush, the diameter of which 5 in. from the pistol end is about 2 in. Objects to be plated are operated upon by pointing the pistol normally to the surface to be coated at any moment at about 5 in. distance and traversing the pistol across the surface with a regular motion. A single coating is about 0.001 in. thick. The operator's vision easily guides him in distinguishing between the coated and uncoated portions and also between a first and second coat.

Two thousandths of an inch well impacted upon a surface are just as effective as a much greater thickness and of course unnecessary sprayed metal increases the cost, as the latter is directly proportional to the thickness. Not only on the score of economy but also to preserve toughness the coating should be of minimum thickness for the anvil action of the metallic spray on a solid metal object is lost above a few thousandths of an inch thickness and a process of cold working follows which produces a brittle scale readily detachable. In practice this matter is easily regulated.

Fig. 5 shows the pistol held in the hand ready for action with the wire thread in position.

Gas bombs with fittings and air at 40 lb. pressure are the only requisites besides the pistol and its hose connections for plating non-metallic objects such as wood, stone, paper, cement, cloth, etc. All metallic surfaces should have the scale cleaned off and their pores opened by preliminary sandblasting.

It will be seen from Table 2 that 0.001 in. thickness, one square foot in area, can be sprayed with the common metals for a small sum. The total cost for German silver is 3½ cents, for copper, 3 cents, for tin, 5 cents, for brass, 2¾ cents, for zinc, 2 cents, for aluminum, 1¾ cents and for lead 1½ cents per square foot.

Various theories have been offered to account for the plating properties of the metal spray, but it is believed by those putting it to practical use that, except in the few cases where the impacted metals have a chemical affinity, the action of the spray is purely mechanical.

Any metal wire can be sprayed with varying degrees of fineness by the pistol, but a hard metal, such as copper, cannot be impacted with the same degree of adherence upon a solid copper object as it would be upon a more porous cast iron object or upon one of the soft metals such as lead or zinc. The

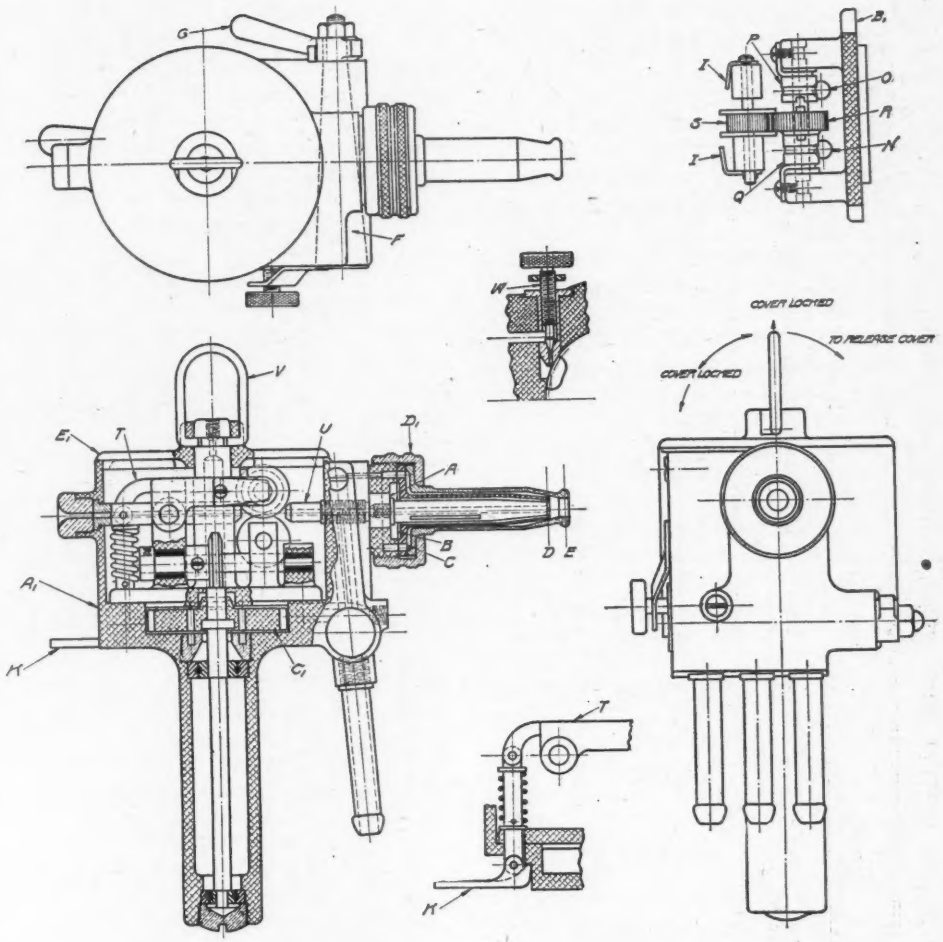


FIG. 6.

coatings may be ground, polished and buffed like any ordinary metals, but polished sprayings do not offer themselves as economical substitutes for cheaper and less adherent platings which are deposited in smooth condition.

As metal spraying is essentially a kinetic energy process the degree of adherence obtained in any instance depends upon the relative hardness and porosity of the sprayed metal and its base. For some decorative purposes this is of no consequence, but where stress, wear and chemical action are involved it is quite important to choose the appropriate coating.

In spraying where the softer metal forms the object, the body of it, as well as its superficial pores, will be penetrated by the harder metal with its projectile action. When the condition is reversed the softer spraying metal will fill the open pores of the harder object and key itself into the former in cooling off, but it will not penetrate the solid parts of the body. In either case, however, with proper preparation of clean open surfaces a durable adherent coating is obtainable.

The detachable coatings form an interesting study and have yet to be developed for many of the arts. It has been found that if the Schoop spray be turned upon a smooth greased surface of reasonable hardness, the bombarding fog of metal particles will remain upon the surface without impacting and will copy the surface to its finest line or detail. On cooling and tapping this reverse it detaches

TABLE 1 DETAILS OF THE COST OF USING METAL SPRAYING PISTOL ONE HOUR

Metal	Diameter, Inches	Speed of Wire in Feet per Min.	Pounds per Hour	Oxygen			Blau Gas			Labor per Hour	Cost of Air per Hour	Cost of Spraying	Wire Cost per Hour	Total Cost per Hour	Total Cost per Minute
				Gauge Pressure	Cubic Feet	Cost at $.02 Cu. Ft.	Gauge Pressure	Cubic Feet	Cost at $.008 Cu. Ft.						
Copper	.032	12	2.15	27	24	$.48	25	13	$.104	.30	$.20	$1.08	$.366	$1.446	$.0241
Brass	.032	12	2.15	28	21	.42	26	14	.11	.30	.20	1.03	.335	1.365	.0228
Bronze	.032	12	2.15	27	24	.48	25	14.5	.116	.30	.20	1.09	.432	1.522	.0253
German Silver	.032	12	2.15	28	23	.46	26	14	.11	.30	.20	1.08	.545	1.625	.0271
Aluminum	.0375	16	12	19	36	.72	16	13	.104	.30	.20	.32	.44	.76	.0127
Zinc	.0375	18	4.3	15	20	.40	13.5	10	.08	.30	.20	.98	1.23	2.21	.0368
Lead	.076	25	30	14	20	.40	12	8	.064	.30	.20	.964	3.00	3.964	.0661
Tin	.061	25	15	13	24	.48	14	10	.08	.30	.20	1.06	10.50	11.56	1933

TABLE 2 COST TO COVER ONE SQUARE FOOT BY SPRAYING

Metal	Diameter, Inches	Speed of Wire per Minute	Time to Cover One Square Foot		Thickness, Inches	Cost of Spraying	Cost of Wire	Total Cost
			Min.	Sec.				
Copper	.032	12	1	10	.001	$.021	$.0076	$.0286
Brass	.032	12	1	10	.001	.020	.0071	.0271
Bronze	.032	12	1	10	.001	.024	.0101	.0341
German Silver	.032	12	1	10	.0089	.024	.0105	.0345
Aluminum	..	16	..	40	.001	.0128	.0042	.0170
Zinc	..	18	..	30	.0015	.0081	.0115	.0196
Lead	.076	25	..	25	.002	.0064	.021	.0274
Tin	.062	25	..	30	.002	.0088	.0875	.0963

TABLE 3 COST OF SPRAYING ONE POUND

Metal	Feet per Pound	Speed of Wire in Feet per Min.	Time to Spray One Lb.	Cost of Spraying	Cost of Wire	Total Cost
			Min.			
Copper	340	12	28	$.50	$.1725	$.6725
Brass	350	12	28	.47	.1625	.6325
Bronze	344	12	28	.53	.2225	.7525
German Silver	330	12	28	.51	.25	.76
Aluminum	761	16	48	1.075	.37	1.445
Zinc	283	18	14	2.27	.33	2.60
Lead	50	25	2	.032	.10	.132
Tin	105	25	4	.07	.70	.77

readily and by using it as a mold and repeating the treatment with a film of grease, a detachable copy of the original object, a coin, medal or any relief subject can be obtained in any desired metal.

Tables 1 to 3 show the data of gas consumption and total cost of spraying a square foot 0.001 in. thick of some of the commoner metals by means of the Schoop pistol; also, the cost of spraying per pound and by the hour and the rate of deposition.

[When the paper, of which only an abstract is given above, was presented at a regular monthly meeting of the American Society of Mechanical Engineers in the Engineering Societies Building a practical exhibition of the process in operation was given in the basement. Various objects were coated by the spray the favorite souvenir being a metal coated visiting card "sprayed while you wait."]

FRESH AIR PARADOXES

It is an undeniable fact that a room filled with air which, so far as chemical analysis can detect, is absolutely pure may feel very stuffy. For instance, the House of Commons, on the ventilation of which the author has experimented for many months for the Committee of the House, the air in the debating chamber is, chemically speaking, as pure as in any room in the world. Fresh air simply pours into it in extravagant volumes. In a moderately full house there are no less than 13,000 cubic feet of air supplied per head per hour. Yet it produces, without any possible doubt, the effects which we are accustomed to think of as associated with defective ventilation—lassitude, sleepiness, infection, and so forth. Complaints are loud and quite general. A room may, on the contrary, feel fresh and sweet in which, judged by chemical standards, the air is very bad. The author has analyzed air containing 25 volumes per 10,000 of CO_2 which felt as fresh as a spring morning, although 10 volumes is regarded as the extreme allowable impurity in current science. There must be some combination of chemical or physical conditions which accounts for the effect, so far as it is objective; when it is purely subjective, of course, it is impossible to analyze the effect. Nobody up to the present has ventured to specify what is that combination.—*A. H. Barker, Transactions of the Society of Engineers.* (British).

THE TESTING OF AIR COMPRESSORS*

When considering the purchase of an engine or machine of any description, the intelligent buyer not only looks upon the first cost, but also on the really more important question of running efficiency, and, therefore, besides obtaining an estimate of the price of the plant, he generally requires some guarantee of efficiency. In addition to this, in order to put a check on the optimism or possible deception on the part of the manufacturer, he specifies some test which will show him whether the guarantees given have been fulfilled. The methods of testing have become a matter of common practice with most classes of machinery. The steam engine is indicated and the steam consumption measured. The gas or oil engine is generally tested by brake, in addition to the taking of indicator cards and the measurement of fuel consumption; while with electrical machinery, the accuracy of electrical measuring instruments has rendered the testing of such plants a matter of exact science. With the air compressor, however, the position is somewhat different. Although there are considerable opportunities for loss in the transformation of heat or electric energy into the form of compressed air, there is a great deal of ambiguity in the method of guaranteeing efficiencies for this type of machine, and frequently very little care is taken to ensure an accurate test.

In the present day compressed air has a very wide field of utility in the operation of underground mining machinery, also in working pneumatic tools in shipyards, steel works, etc., and it would seem of no small importance to the user of such plants, and also the manufacturer, to standardize both the way of stating the efficiency of the machine and the method of testing it on completion. Usually there are three things specified in some form or other concerning the expected performance of an air compressor, namely, the volumetric efficiency, mechanical efficiency, and the power consumption for any given quantity of free air at the required pressure.

VOLUMETRIC EFFICIENCY.

The volumetric efficiency, which is very often treated as of greater importance than it deserves, is, of course, merely the ratio ex-

**The Engineer,* London.

pressed as a percentage between the actual volume of free air compressed in a unit of time, and the volume swept by the first-stage piston or pistons in the same time. While it is important to the manufacturer to obtain a high volumetric efficiency, as this means that the size of the cylinders and consequently of the whole machine is reduced to a minimum for any given duty, it is not of paramount importance to the buyer, except in so far that a high volumetric efficiency tends towards a high mechanical efficiency and low power consumption. It is of very little moment to the buyer whether the cylinders of his compressor are large or small, within reasonable limits, if at the same time his machine will give the required output with small consumption of energy, and, in fact, it might even be a matter of suspicion if an exceptionally high volumetric efficiency was specified, as in such a case the cylinders worked out on this assumption might prove on careful testing to fail to give the full quantity of air specified.

Of the two main causes of loss of volumetric efficiency, excessive clearance and excessive heating, the latter is by far the most important, for while the former merely reduces the quantity of free air taken in per stroke, the latter also entails an actual loss of energy; this lost work being converted into heat, carried away by the cooling water or dissipated by radiation from the cylinders and pipes. It is, therefore, in this direction only that a high volumetric efficiency tends to economy in working, but, as will be explained later, this economy in working can be indicated more definitely in other ways. It may, however, be here stated that the volumetric efficiency obtained in well-designed compressors may be as high as 98 per cent. for large units.

MECHANICAL EFFICIENCY.

Dealing with the second efficiency mentioned, namely, the mechanical efficiency, this expression appears to be invested with a different meaning in different cases, and we also sometimes meet such expressions as "commercial efficiency," which, while being a form of the former, has no generally accepted meaning or definition. As most commonly understood, the term mechanical efficiency is taken to mean the ratio of the *air* indicated horse-power to either the indicated horse-power of a steam-driven compressor or the brake horse-power at the compressor shaft in the case of a compressor driven by electric motor. Not quite the same thing, as the ratio $\frac{\text{A H P}}{\text{B H P}}$ is generally higher than $\frac{\text{A H P}}{\text{I H P}}$, for the reason that this last must take into consideration the losses due to friction, etc., of the steam engine portion of the compressor, with its steam valves, governor, etc., which are absent with the electric drive. It will be seen that in either case these figures are based on indicator diagrams, and while the indicator applied to air compressors gives most valuable information, and indicator cards should always be taken, the results obtained are by no means conclusive from the buyer's point of view. Either of the ratios mentioned above, taken in connection with other information, give considerable assistance in comparing the merits of a compressor, but it must be remembered that a high mechanical efficiency can be equally well given by a *high* air horse-power as by a *low* brake horse-power or steam indicated horse-power. It can be easily conceived that an inefficient compressor showing an unnecessarily high air horse-power for a given output, when compared with the brake horse-power at the motor shaft, may show a very fair efficiency, while at the same time it may be very uneconomical in power consumption.

POWER CONSUMPTION.

We come now to the third and most important form of guarantee from the buyer's point of view, namely, the power consumption for any given quantity of free air compressed to the required density. This is analogous to the steam consumption per indicated horse-power of a steam engine, in the same way that the mechanical efficiency, as explained above, is analogous to the mechanical efficiency of a steam engine, the former giving an indication of the cost of production of a definite quantity of power, while the latter merely indicates how much of the lost power is due to engine friction, and in an air compressor the power lost in friction is usually a very small portion of the total loss incurred in the transformation of energy into air pressure.

It is the usual practice of builders of air-compressing machines to state the power consumption, either in brake horse-power at the compressor shaft or indicated horse-power of

the steam engine, for electricity and steam-driven compressors respectively, and this information may be most suitably converted for the purposes of comparison into cubic feet of free air per minute compressed to the required pressure per brake horse-power or indicated horse-power input. This is certainly the expression which will convey to the user in definite figures the cost of running his plant. A compressor of modern and efficient design will require one brake horse-power at the shaft for about 5¼ cubic feet of free air compressed to 100 lb. per square inch. A larger or smaller expenditure of energy will be required when the final pressure required is lower or higher than 100 lb.

The most scientific way of stating the efficiency of a compressor is to compare the actual brake horse-power absorbed at the compressor shaft with the horse-power which would be theoretically required to compress the given quantity of air to the necessary pressure under ideal conditions. This absolute standard of comparison is best taken to be the theoretical horse-power required when the air is compressed isothermally. Of course, as need not be explained here, isothermal conditions are never obtained in practice, and actually the compression curve approximates more closely to an adiabatic curve. Still, isothermal compression represents the desired ideal, and has the necessary qualification for purposes of comparison, of being invariable for any given quantity of air and pressure. The formula for the horse-power required when the air is compressed isothermally is well known, and may be stated here as

$$HP = \frac{144}{33{,}000} \times P^1 V \left(\log \frac{P^2}{P^1} \right)$$

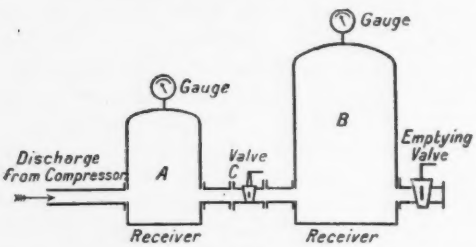
; where P^1 = initial pressure (usually that of the atmosphere, 14.7 lb. per square inch), V = free air volume, and P^2 = final pressure. On this basis the efficiency

$$\frac{\text{A H P (isothermal)}}{\text{B.H.P.}} \times 100$$

in practice varies between 60 per cent. and 80 per cent., depending very much on the size of the unit under consideration. Large, slow-speed compressors frequently show the higher efficiency mentioned, and smaller high-speed machines the lower. This gives a very convenient expression for the efficiency of an air compressor, which might be with advantage generally adopted. For purposes of investigation, the *isothermal* air horse-power may be compared with the *indicated* air horse-power, as the ratio obtained in this way will give a measure of the losses which occur in the actual compression of the air, independent of frictional and other mechanical losses in the machine.

To return, however, to the buyer's point of view, he purchases a compressor which is guaranteed to compress a certain quantity of free air to the required pressure with a consumption of power not exceeding the specified amount. He may, therefore, very reasonably desire to test the machine either at his own, or the maker's works, to see that these conditions are fulfilled. To do this, the air pressure obtained is easily measured by a suitable gauge. The horse-power absorbed, also, is found by taking indicator cards from the steam cylinders in the case of a steam-driven compressor, or by electrical measuring instruments, when the machine is to be driven by an electric motor. The only difficulty is the measurement of the quantity of air compressed, and the easiest and most reliable way of doing this is by means of a suitable receiver, the capacity of which has been carefully calibrated. But here a difficulty presents itself. It is quite usual to discharge the air into one receiver, noting the time which is taken in raising the pressure of the air from that of the atmosphere to the required final pressure. It will easily be seen that this is not a test under practical working conditions, insomuch as the quantity of air measured in the receiver has not all been discharged at a constant pressure, and that the specified final one desired. For, at the start, the compressor is only discharging against atmospheric pressure, and it is not until the test is completed that it has to pump against the maximum working pressure. The horse-power absorbed will, therefore, vary throughout the whole period of time required to raise the pressure in the receiver to the required intensity. However, this method of ascertaining the actual output from a compressor is very generally adopted, and it is pointed out that, if the horse-power measurements are taken at a moment approaching the end of the test, fairly accurate results are obtained. But quite apart from the question of power consumption, it is not an accurate test of the actual volumetric capacity of the machine, and it

is quite possible that, while a compressor will deal with the requisite volume of air when tested under these conditions, it would fail to do so if the discharge had to be maintained continuously, during the test against the maximum working pressure. For, during the commencement of the trial, when the receiver pressure is low, none of the most active causes of loss in volume come into full force. The heating of the air is neglible at low pressures, as is also the leakage past the valves, etc. Again, at higher pressures, the loss of volume due to the re-expansion of the air imprisoned in the clearance spaces has a greater effect. It is almost un-necessary to labour these points, and it may be assumed that the right way to carry out a test is to measure the air in a receiver which has been filled against the maximum working pressure, this pressure remaining constant during the whole period of the test. This may easily be done by means of



MEASURING AIR OUTPUT.

two receivers in series, as shown in the accompanying diagram. The discharge from the compressor is led first into the receiver A, which is filled with air until the gauge attached reads the required pressure, the valve C being closed meantime. As soon as this pressure is reached in A, the valve C is opened just sufficiently to maintain this pressure. The amount of opening at C will then be just sufficient to pass the full discharge of the compressor, which will flow into the second receiver B; the time being noted between the opening of the valve C and the moment when the gauge on receiver B also indicates the specified pressure. This will give the time occupied in filling this receiver, the capacity of which is known, against a constant and predetermined pressure. From this it is a matter of simple calculation to obtain the rate of discharge from the compressor. By means of opening additional discharge valves on A and B, and closing valve C, B may be emptied, and when the pressure of its contents has fallen to that of the atmosphere, it may be refilled, and the test repeated as many times as may be thought necessary. With care in manipulating the valves, any serious alteration of the discharge pressure can be avoided, so that measurements of power consumption can be taken continuously, and a full load test of the compressor extended over several hours. The only objection to this method of testing is that of the cost of providing two receivers, but it will be seen that the first vessel A need only be large enough to ensure a steady pressure reading, and even a sufficient length of piping will serve. The final receiver B should be as large as can be arranged for, to ensure accuracy of results, and should be carefully cali brated.

It need not be pointed out that the volume of air at the working pressure to be measured must be calculated from the free air volume specified for the compressor, and the usual corrections made for temperature. A suggestion will at once present itself, namely, that the valve C, between the two receivers, is empirically adjusted to given an orifice capable of just passing the required volume of air which is flowing from the first receiver under the specified working pressure. It would, therefore, be quite practicable to measure the flow from a compressor by means of an orifice of calculated area at the outlet of the first receiver. This is, in fact, sometimes done. In order to calculate the area of this orifice correctly, the coefficient for the jet must be known, as in the case of measuring the flow of water over a weir. Unfortunately, there do not appear to be any data available for this purpose, and it would require some experimental tests to obtain the necessary information.

There is one other point worthy of note in connection with the testing of air compressors. That is the measurement of the power consumption at light loads. Owing to the fact that an air compressor frequently works a great part of its working life at a load considerably less than its full rated capacity, it is very important that such a machine should be economical at light loads. A compressor may take very little power to drive it when delivering the full specified quantity of air, and at the same time be extravagant of power on

light loads, with the result that it will prove to be uneconomical in running on the average load under working conditions. It is, therefore, advisable that the buyer should obtain a guarantee of power consumption at light load, and carefully test the machine at varying loads.

LOST MOTION IN ROCK DRILLING

BY LETSON BALLIET.

The energy delivered by the human power plant is far more expensive per horsepower hour than that delivered by the mechanical power plant.

There are many expert mathematicians among the mining engineers, but if we assign a problem asking what per cent. of the motions made by the human power plant are lost or wasted motions, we fear that there are few who can solve the problem.

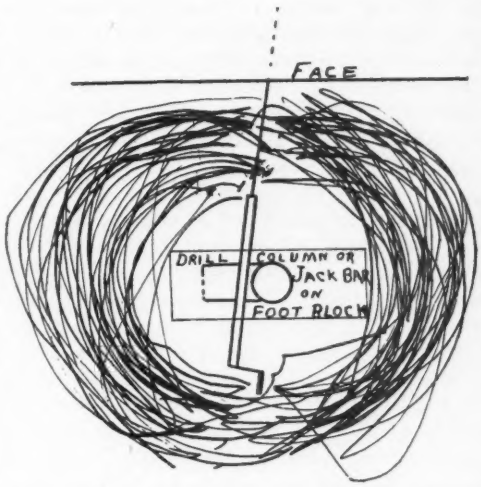
The lost motions and wasted energy of the human power plant are not only fatiguing, but mentally discouraging to the workers. Efforts without result are heart-breaking to the workman. No man can accomplish the same amount of work when he is discouraged as when every motion counts. It is the question of results that makes his labor efficient or inefficient.

Mining is now prosecuted, almost entirely, by means of machine drills, and we will admit that they have a great advantage over hand drilling, but the manufacturers of machine drills have rested content with the primary arrangement apparently without attempting to bring out anything more convenient.

ROCK DRILL INEFFICIENCIES.

One excessively inefficient point of the machine drill is the feed-screw operated by a crank from behind the drill which keeps the machine operator from 4 to 6 ft. away from his work. This disadvantage is serious when machines are to be operated by one man.

As a matter of graphic illustration a chart has been prepared showing the foot of the jack bar on its foot block, while the diagram which accompanies it shows the path of the operator in his trips around the drill column. Part of the time he had to crawl under the drill arm, or the air hose, and part of the time he went the other way around. Of course, it would make it easier walking if he were provided with a large rubber mat to surround the jack bar, but it wouldn't eliminate the lost



motions. It would seem that if the drill was so designed that the cranking could be done from the forward side of the shell, or from beneath the chuck, that several hours of time could be saved that are now spent *traveling around the jack bar.* This travel around the jack bar ordinarily means from 3 to 5 steps, or perhaps a distance of 8 or 10 ft. of actual travel each way.

THE DRILL RUNNERS TRAVELS.

Let us assume that the driller goes forward, or changes sides 25 times in 8 hours, moving a distance of 8 ft. with each change while putting in a round of 10 or 12 holes in hard ground. This includes changing steel, tightening chuck nuts, releasing drills that stick in the holes, throwing water with a can or dipper into the hole, adjusting hose connections or water feeds of some kind, throttling and cranking the machine, etc.

Seventy-five trips around the machine 8 ft. each way, or 16 ft. for the round trip, computes nearly a quarter of a mile of travel over hose and blocking, stooping under the drill or the arm, etc. The question is: Why don't you take up some of that quarter mile of lost motion if you are so particular about a sixty-fourth of an inch in the crank pin of an engine or compressor?

If you are in doubt as to the accuracy of these figures, take a piston drill into a hard face, say nothing to the operator, but check up his lost motions in traveling around the column from the set-up to the tear-down, and see for yourself the chart you can make.

Use a stop-watch and see how much time he uses in changing position. Notice the number of times he hammers the drill steel with the chuck wrench to release it when it sticks, while if he was standing alongside of the steel he could keep cranking and hammering at the same time.

SOME HORSE-POWER FIGURES.

You are paying perhaps from 1 to 5 cents a horse-power hour for steam, gasoline or electric power, and you make strenuous efforts to save a fraction of an inch of lost motion. You are paying 50 cents per man-power hour, and waste a quarter of a mile of lost motion.

If 33,000 ft. lb. per minute equals 1 h. p., we will take the actual work of loading a car to figure how much horse-power the average man develops. One man loading a 1-ton car raises 150 shovelfuls of muck to a height of 4 ft., and loads the car in 10 minutes. Thus the man lifts 2,000 lb. 4ft., equaling 8,000 ft. lbs.

This would be practically one-fourth of a horse-power if done in one minute, but as it took 10 minutes the man's working rate was one-fortieth of 1 horse-power. Under the conditions existing in most mines the human labor actually figures about one-fortieth of a horse-power, and if paying the man 50 cents an hour, or $4 a day, the human power plant is costing $20 per horse-power hour.

Now the question arises: Why do you figure your mechanical power down to a few cents per horse-power and struggle to save a fraction of an inch of lost or wasted motion, while you allow miles of lost motion in the human power plant where the power costs $20 per horse-power hour?

This article is frankly aimed at the drill manufacturers, calling attention to the increased efficiency they could develop if they would design their drills so that the feed screw could be cranked from the forward end of the shell. This could be very simply arranged through gears, a worm or a ratchet, or by having a skeleton shell with the feed nut low enough to allow the crank to be turned underneath the chuck, or perhaps a little to one side. This construction is up to the drill makers, and if the mining operators will demand this arrangement of the feed screw they will greatly simplify the problem of the 1-man drill, and do away with chuck tenders.

TO KEEP THE DRILLS WORKING.

Careful timing of mounted rock drills, over a long period of time, shows that the drills are not working one-third of the time. Setting up, shifting, changing steels, getting water, getting steel, oiling, cleansing, fighting with stuck drills, tearing down and blasting, take up more than two-thirds of every drill shift.

The inventive ability of the drill makers is working upon the short end of the subject, when they try to make improvements that will result in more holes by faster cutting machines. It is true that faster drilling has some advantages, but if a round of holes is a shift's work," the reduction of drilling time to 25 per cent. of the 8 hour shifting simply leaves 75 per cent. of the shift for dead work. To blast ahead of time is often dangerous, and to wait for the smoke to be cleared out uses the rest of the shift, anyway. To put in deeper holes and blast a bigger round is often more inconvenient than a shorter round, for there is but little use in blasting out more than a mucker can clean up on his shift.

As it is shown that 66 to 75 per cent. of the time occupied on a drill shift is dead work, performed by human power, while 33 per cent of the time only is the machine using air power, it would seem that some inventive effort would be put forth to make a quick and easy set up, a quick and easy method of changing steel, and a quick and easy method of shifting the machine on the bar.

We simply cannot see why so much effort is given to save a small part of the drilling time, while no effort at all is put forth to save any of the larger percentage of wasted time when not drilling.

[The above suggestive article, reproduced in somewhat condensed form from *Mining World*, provokes the question as to why it was not written a few years earlier. Instead of trying to cobble up some contrivance for turning the feed screw by the other end as suggested the drill builders have done much better than this and have given us air-feed drills, and the Jackhamer which has no mechanical feed at all and does more work than any of them.]

Simultaneous blasting is estimated to be 25 per cent more effective in breaking rock than the firing of holes consecutively.

CHEAPER AND BETTER THAN ACETYLENE

BY J. F. SPRINGER.

The gases commonly employed in autogenous welding and cutting are oxygen, acetylene and hydrogen, all of which are expensive products. The average cost of oxygen throughout the United States is probably not less than $0.025 per cubic foot measured at atmospheric pressure; the average cost of acetylene probably ranges from $0.0075 to $0.01 per cubic foot; and the cost of hydrogen may safely be placed at about the same figure. Apparently no one has yet devised a system of oxygen manufacture that will enable this gas to be inexpensively produced. However, there appears to be a likelihood of heavy reduction in the cost of the fuel gas used in autogenous welding—not through a reduction in the cost of acetylene or hydrogen, but through the discovery of an adequate substitute for these gases. This substitute is a semi-natural gas obtained from the waste gas from oil wells, and is known as "gasol." It can be produced at about $0.001 per cubic foot, and its heating capacity is even greater than that of acetylene. Other things being equal, this gas selling for $0.0008 to $0.001 per cubic foot should have a considerable advantage over acetylene or hydrogen selling at $0.008 to $0.01—ten times as much.

Name of Gas	Cubic Feet of Oxygen required to burn one Cubic Foot	Heat Value in B. T. U. per Cubic Foot	Cost of 1000 B. T. U.
"Gasol".....	2	2300	$0.00162
Blau Gas. ...	2	1800	$0.00213
Acetylene	1½	1500	$0.00217
Hydrogen.....	2	500	$0.008

COMBUSTION FIGURES FOR DIFFERENT GASES.

Note: The above figures are based on the following prices: oxygen, 1½ cent per cubic foot; "gasol," 10 cents per pound; blau gas, 10 cents per pound; carbide, $70 per ton; and hydrogen, 1 cent per cubic foot.

In addition to the advantage in price, there is an economy in handling this new fuel gas. It is collected at the point of origin and compressed into liquid form, the liquid gas being shipped to the user in a suitable steel container. As the weight of the liquid gas in a container is equal to the weight of the container, an economy is effected in transportation costs. The gas issuing from the oil well, which is collected and compressed into the liquid form, is of variable composition, containing various percentages of hydro-carbon gases. The constituents of a typical sample of the crude gas as collected at the oil well include gases known as methane, hexane, butane, propane, and ethane mixed with more or less water and vapor. These constituents of the crude gas may be liquefied by the application of various amounts of pressure, the temperature remaining the same; or they may be brought to the liquid form by reductions in temperature, when the pressure remains constant.

All the gases with the exception of methane may be liquefied by the application of a moderate pressure under ordinary temperature conditions. But at 10 degrees F. it requires a pressure of 2700 pounds per square inch to liquefy methane, and this is obviously beyond commercial possibilities. At the maximum temperature which the gas will encounter during transportation, the pressure necessary to bring about the liquefaction of methane is impractical. The expense of the container would either be prohibitive or there would be a constant danger of the container exploding. These considerations make it necessary to eliminate the methane from the crude gas before it is liquefied, and as the heating value of methane is considerably below that of hexane, butane, propane or ethane, the elimination of the methane results in the production of a residual gas of higher heating value. However, the heating value of methane is not to be despised, and this gas is used in the locality where the residual gas is liquefied.

By applying a pressure of from 850 to 900 pounds per square inch to the residual gas at ordinary temperature, the gas will be brought to the liquid condition. This pressure can be readily obtained in practice and the cost of containers which will safely withstand the pressure of the gas is not excessive. The liquid gas has a specific gravity of about 0.5, or one-half that of water. One quart of the liquid weighs about 1 pound and produces approximately 10 cubic feet of gas. The containers in which the gas is shipped weigh approximately 100 pounds and have a capacity for 100 pounds of the liquid; accordingly, they hold approximately 1000 cubic feet of gas, which has a total heating value of about 2,000,000 B. T. U.

Natural gas requires an unusually large

amount of oxygen for its combustion, but the gas evolved from the "gasol" liquid contained in the cylinders requires still more oxygen for its complete combustion. As a result, it will be evident that the burner of the welding torch must be designed to deliver a higher amount of oxygen relative to the fuel gas than is the case where acetylene is used. At first thought, it may appear that the relatively higher consumption of oxygen will largely offset the advantage of the lower cost of the fuel gas. This is not the case, however, as less of the liquid gas is used to do a given amount of work because its heat value is relatively higher than that of acetylene. A further economy would also be effected through saving the first cost and maintenance expense of an acetylene generating plant. In the event of this substitute for acetylene finding wide application, the manufacturers of cutting and welding equipments would not be seriously affected, as essentially the same type of apparatus could be used. No doubt it would be necessary to make certain modifications in design, a case in point being in respect to the relative cross-sectional areas of the oxygen and gas ducts in the torch, but aside from changes of this nature, the welding and cutting of metals with "gasol" would be the same as when acetylene is used.—*Machinery.*

CEREAL DUST EXPLOSIONS

BY DAVID J. PRICE.*

A total of 19 explosions that have occurred during the past 10 years have been carefully studied and investigated, with a view to determining the causes and circumstances under which they occurred. Of the 19 explosions referred to, 11 have taken place since this work began in August, 1913. Since we have a record of only 8 explosions of this nature from 1905 to 1913, and a larger number in the short period from August, 1913, to the present time, we may reasonably conclude that the recent occurrences have been given special notice and attention since the study began, or that modern advanced and improved mills are experiencing more occurrences of this nature at this time.

It is reported that as a result of these explosions at least 80 men were killed and 125 injured, with a property loss exceeding $2,000,000.

*Engineer Bureau of Chemistry, U. S. Department of Agriculture.

SUPPOSED CAUSES OF THE EXPLOSIONS.

The establishing of a direct cause of a cereal-dust explosion by investigation directly following the occurrence has been found in some cases to be extremely difficult, while in others certain lines were distinctly defined and definite causes could be fairly well determined. The result has been that in a large number of cases the cause could not be definitely established.

Eight explosions were thought to have originated from sparks produced in the machine during the grinding process, one was attributed to production of static electricity, and in the remaining 10 occurrences it was not possible to establish a definite cause of the origin.

Although it has been claimed that sparks produced by foreign matter in the grain fed to the grinders might not possibly be sufficient to ignite the dust, the evidence in the majority of cases referred to was conclusive as to this particular cause. In order to definitely determine the relation of the sparks produced in this manner and a suspended dust cloud, an experimental mill has already been erected at Pennsylvania State College.

It is not possible to state at this time what effect a high ash content has upon the inflammability of "cereal dusts," for no work has yet been done along this line; but it has already been found that elevator dusts with as high as 16 per cent. of ash are very inflammable and develop high pressures on ignition.

From the investigations already conducted relative to the causes of cereal-dust explosions that have occurred in recent years in this country and abroad the following causes may be advanced:

1. Introduction of foreign materials into grinding machines.
2. Use of open lights or naked flames, such as oil lamps, torches, gas jets, lanterns, candles, matches, etc.
3. Property fires.
4. Electric sparks from motors, fuses, switches, lighting systems.
5. Static electricity produced by friction of pulleys and belts, machinery parts, grinding machines, revolving reels, etc.

STATIC ELECTRICITY.

The first four causes given may possibly be generally accepted but the advancement of the

last cause, namely, "static electricity" has opened, as it were, a new field.

In September, 1913, on a dry frosty morning in early fall two slight explosions occurred in separate plants in Western New York, at a time when the feed had been shut off from certain grinding machines. The occurrences took place after considerable lapse in time after the stream of grain had stopped entering the machines. The possibility of "static electricity" being produced by the operation of the revolving plates of a machine suggested itself in a very preliminary way at the time of these occurrences.

Although up to that time experiments had not been conducted to determine whether cereal dusts could be ignited in this manner, it was found by experiment that sufficient static electricity could be produced by friction of a very small pulley and belt to readily ignite natural gas. It was learned at this time that a milling company in the South, engaged in grinding cotton-seed cake into meal, after experiencing a series of explosions, had prevented a repetition of previous occurrences, by grounding the grinding machines, by means of a wire connected to a rod driven in the ground nearby. This confirmed the original theory and indicated the practical success of a grinding device of this kind.

The possibility of static electricity as a source of cereal-dust ignition was very clearly established by an explosion in the dextrine department of a starch factory in one of the Eastern States in September, 1914. The origin of the explosion was traced to the production of static electricity by friction of particles of dextrine on 80-mesh brass gauze surrounding a revolving reel. This reel was only revolving at the rate of 16 revolutions per minute at the time of the explosion.

It is of very great interest to note in connection with this explosion that the company had grounded this reel to an overhead sprinkling system at the time of this explosion. It was found during the investigation, however, that the connection was made from the journal box, and that a heavy film of fresh oil surrounded the shaft. This was thought to have served to insulate the shaft and allow the static to accumulate within the reel until there was sufficient charge to ignite the dextrine dust.

It has recently been found by an English scientist that if a cloud of dust is blown against an insulated conductor (a wire for instance) the wire becomes charged with electricity, and under certain conditions it may become so highly charged as to give off sparks.

HOW DUST EXPLOSIONS ARE POSSIBLE.

It has been difficult for many to understand in what manner a dust explosion can occur without the presence of inflammable gas at the time of ignition. We may be able to simplify the explanation by stating that we might try for some time with great difficulty to burn a block of wood with a lighted match. If we take a knife and chip the block the shavings will ignite more quickly. We might make excelsior of the block and would find it would ignite still more readily, and so on by gradual reduction to a degree of fineness until dust is produced, when we find that the mass will burn rapidly when in suspension and diffusion with air.

The predominating factor which determines the inflammability of a dust and the action of a dust explosion has not been determined. A number of theories have been advanced, including the amount of volatile matter in the various dusts, together with the percentage of moisture and ash; the rate, or ease, of oxidation and the degree of fineness of the dust. All these have no doubt a marked relation to the action and nature of a dust explosion, and are at present receiving careful attention from the chemists experimenting along this line.

PROPORTIONS OF THE EXPLOSION MIXTURES.

Since experiments have shown that the cereal dusts will ignite and propagate a flame, it will be of interest to consider the question of the amount of dust necessary to propagate a flame. In some of the experiments the dust was diffused in the proportion of .035 ounce per cubic foot of air space, and high pressures developed with the mixtures. To obtain the same proportion of dust and air, producing a mixture as inflammable as used in these experiments, it would be necessary to have only about 10 pounds of the dust in a closed room 10 ft. by 30 ft. by 15 ft.

EXPERIMENTAL EXPLOSIONS.

It is interesting to note at this time that, following the explosion in Minnesota in 1878,

Profs. Peck and Peckham found that 2 ounces of flour dust diffused with 2 cubic feet of air, when ignited in a box with flame, would produce an explosion sufficient to lift two men standing on the cover. It has been calculated that a sack of flour suspended as dust in 4,000 cubic feet of air (a room 20 by 20 by 10 ft.) when ignited would generate sufficient force to throw 2,500 tons 100 feet high.

Explosions have been produced at the Pittsburgh Testing Station of the Bureau of Mines when there was only .032 ounce of coal dust suspended in each cubic foot of air, or 1 pound in 500 cubic feet. In order to produce combustion it takes all of the oxygen in 1 cubic foot of air to completely burn .123 ounce of the dust used. In France ignition was obtained in one instance with as low a weight as .023 ounce of coal dust per cubic foot, while at the German Testing Station ignitions have been obtained when .04 ounce of coal dust was suspended in 1 cubic foot of air.

Preliminary experiments have shown that many cereal dusts have relatively a lower ignition temperature and produce higher pressures than the coal dusts. We might therefore conclude that the explosive limits would be lower with cereal dusts than the figures given for coal dust.

REMARKABLE CAVE IN COPPER MINE

The Michigan College of Mines has received a beautiful collection of minerals from the celebrated Shattuck Cave, near Bisbee, Arizona, one of the seven wonders of the mining world. This cave was opened in 1913 by a drift on the third level of the Shattuck Mine. When the miner who had been drifting in this part of the level returned one night after a heavy blast, he found that the working face had entirely disappeared and that before him was a great opening reaching farther than his light would shine. Looking upward he could see tiny lights flashing and believing that they were stars he ran back to the shaft, declaring that he had blasted a hole clear through to surface.

Mine officials investigated at once and found that a great natural cavern had been opened up, circular in shape, 340 feet in diameter and 175 feet high. It was a virtual fairyland of beauty, myriads of crystals in the roof reflecting back the lights from the miners' lamps. Walls, roof and floor were covered with great clusters of crystals, and near the center of the cavern a cluster of stalactites hung from the ceiling in the form of a great chandelier 40 feet long. The crystals were for the most part pure white, but in places where the filtering waters had contained iron and copper, the beauty was enhanced by great transparent stalactites and stalagmites, some ruby red, others a clear emerald green or azure blue.

The mining company illuminated the cave with electricity and has allowed thousands of visitors the privilege of seeing it. It is because the mine operators have now found it necessary to fill the cave with waste rock that the Shattuck-Arizona Mining Company sent the specimens to the College of Mines.

ASPHYXIATING GASES IN CIVILIZED WARFARE

Our esteemed contemporary *Le Genie Civil* gives an exceedingly interesting article on the use by the Germans of asphyxiating gases, and of the means which have been taken to render this form of attack harmless. Our contemporary points out that the use of these gases is contrary to Article 23 (*a*) of the Hague Convention, but adds that the enemy had previously and by official command broken the prescriptions of that convention, since in the early months of the war he had not hesitated to employ jets of burning liquid in numerous actions. It appears that the Germans had prepared corps of men specially instructed in the use of these discreditable methods of warfare. But, adds our contemporary, success does not always attend the use of the gases. In one case, at any rate, they were blown back into the trenches whence they had come, and, moreover, they depend, in order to be effectively employed, on the conjunction of several circumstances. But that their use has not had more far-reaching results than is actually the case has been because of the investigations which were immediately commenced by the Belgian, British and French authorities, and which, if they did not reveal the exact nature of the gases employed, have at any rate pointed out the way to combat their ill-effects and very largely to reduce their power of doing damage.

In discussing the nature of the gases used, it is stated that, judging by their properties and the character of their effects, there is not much doubt that the chief constituent is chlorine. It is extremely probable, however, that bromine, formaldehyde, nitric oxide, and sulphur dioxide have also been employed; but apparently chlorine has been used in the greatest bulk. The gases have been discharged against the Allies in several different ways:—(1) By lighting fires in front of the German trenches and burning on them substances which would give off noxious fumes; (2) by letting the gases escape from cylinders in which they were stored under pressure; and in this connection it is stated that the price of liquid chlorine in Germany in ante-war times was from 55f. to 85f. per kilogramme, which represents about 20s. to 30s. per pound, so that some idea of the cost of a gas attack may be formed; (3) by throwing either by hand or by means of catapults glass vessels containing compressed gases; and (4) by hurling from guns a kind of bomb furnished probably with a fuse, which exploded on touching the ground, and let free the gases which had been compressed inside the bomb. It does not appear that up to the present projectiles of this nature have been employed in long range guns. The Germans have made extensive use of the first two methods, and particularly of the second. The cylinders for containing the gases are of steel, about 25 cm. in diameter and from 1.2 m. to 1.35 m. long. They are furnished with a metallic discharge tube 20 mm. in diameter and from 1.6 m. to 1.8 m. long, this pipe or tube being given near its extremity a right-angled bend, so that when the cylinder is placed vertically the bent portion of the tube is horizontal. A cock is placed at the junction of the cylinder and the tube so as to control the mission of the gases, and the weight of the cylinder, pipe, etc., is from 60 kilos. to 65 kilos.—*i. e.*, from 130 lb. to 140 lb.

The Germans are accustomed to arrange these cylinders upright in their trenches, with the bent tubes pointing in the direction of the Allies lines, the tubes just coming above the level of the ground. On the cocks being turned the gases are forced from the tubes and spread themselves over the surface of the ground since their density is greater than that of the air—chlorine being two and a half-time as heavy as air and bromine five times. If the ground slopes away from the German trenches and towards those of the Allies, or if there is a gentle wind from one to the other, the gases roll along much in the same way as does water, filling up all depressions. If the nature of the ground permits of it, the cylinders are arranged in groups of three, four or more at intervals of from 20 m. to 30 m.

In order, however, for the gases emitted by this method to be really successful, a variety of conditions have to be fulfilled. First of all, the wind must be in the right direction, and it must not blow too strongly, or it will dissipate the gases; nor must it change in direction, or the gases may get blown back on their senders. Then, again, the air must not be too moist, for the gases are soluble in water and are rapidly thrown down in a condensed form on the ground when the air contains much moisture. It is certainly not to be regretted that it is necessary to have such a conjunction of circumstances, or the gases might be more frequently employed than they are.

The cylinders apparently hold enough to keep on discharging for some twenty minutes at a time. When they are empty they are sent to the rear to be refilled. They are when in the trenches manipulated by special men, who are clothed in a costume very much resembling that of a diver. All the other men in the trenches are provided with masks, which can readily be fixed over the nose and mouth, the masks being provided with cotton pads impregnated with certain salts and with a saline solution which prevents them from getting dry. It is argued that the preparation of the apparatus for producing the gas, the arrangement of the trenches to receive the cylinders, the organization of the service in the rear for refilling the latter, the training of a special corps of men, and the distribution of masks, indicates long and careful preparation, and that premeditation is undoubted, so that the German explanation that the use of gases was in the nature of a reprisal for the alleged use by us of similar gases a day or two before carries no weight whatever. The enemy must have matured his nefarious schemes months beforehand.

Turning, then, to the effects of the gases, the article shows that they were felt 2 kiloms. behind the front line trenches, and the smell could be perceived 5 kiloms. from the point of discharge. In order to cause rap-

id death it is explained that it is not necessary that the air should contain more than one-thousandth of its volume of chlorine. Even if the proportion is only one in one hundred thousand it is dangerous to breathe the mixture for any length of time. With still smaller proportions the person breathing the atmosphere is sensibly affected.

Two methods of dealing with the gases before they reach our trenches are discussed in the article. The first is that grenades or bombs could be discharged in front of the menaced trenches, these missiles being charged with black powder. These, it is explained, would have two effects:—(1) They would dissipate the cloud of vapours, or at any rate prevent it from being continuous, and would dilute the asphyxiating gases by reason of the gases of explosion; and (2) their discharge would produce potassium sulphate, which would react with the chlorine or some of it and greatly minimize its harmful properties. The reaction is shown in the following equation:—

$$K_2 S + 2 Cl = S + 2 K Cl.$$

There is much the same reaction with bromine. The chlorides and bromides formed would be harmless, and sulphur is inert. Or, again, on the approach of the cloud volatile alkalies might be sprayed in front of the trenches. Ammonia is taken as an example. It would have the following reaction:—

$$4 N H_3 + 3 Cl. = N H + 3 N H Cl.$$

It is remarked, however, that ammonia gas is itself suffocating and caustic, and would have to be employed with circumspection, while the chlorohydrate of ammonia resulting from the reaction is a solid body which would form a thick, white cloud, which would be a great deal more opaque than the chlorine or bromine gases.

The best preservative against the bad effects of the gases hitherto discovered consists, it is explained, however, in the employment of a respiratory apparatus similar to that served out to the German soldiers. The first appliance used was a mask with a cotton pad impregnated with hyposulphite of soda. The reaction of the chemicals is as follows:—

$$2 S_2 O_3 Na_2 + Cl_2 = Na_2 S_4 O_6 + Na Cl.$$

Or, if the chlorine be in excess, as is generally the case, the oxidation would be more complete, and sulphuric acid and sodium sulphate produced, thus:—

$$2 Na_2S_2O_3 + 5 Cl_2 + 6 H_2O = 10 HCl + 2 Na_2 SO_4 + H_2SO_4 + S.$$

The hydrochloric acid thus produced is itself a suffocating gas, but it does not produce effects which are in any way comparable with those produced by chlorine. Moreover, the gas would be largely condensed, if not in the wet cotton wool, then, at any rate, in the saliva and would pass to the stomach, which is much better able to resist its effects than are the lungs. If to the hyposulphite were added a small quantity of sodium carbonate, this would also be useful in neutralizing the acids, but then, again, carbon dioxide would be produced.

Quite recently the mask which was always considered unpracticable and not always certain in its action, since it could be so easily knocked off, has been replaced by what is termed a "Cagoule," or monk's cowl, which is a sort of sack worn over the head under the headdress, and which is provided with a horizontal opening closed by a plate of mica, and arranged to come in front of the eyes. The lower part of the sack comes down over the neck, and is buttoned in between the shirt and the vest. The cowl, which before use is steeped in a neutralizing solution, is not found in any way to interfere with respiration nor with the movements of the person wearing it. The chemical reactions take place over the whole of its surface, which is large, the latter fact constituting a great advantage over the mask. The impregnating solution consists not only of hyposulphite and carbonate of soda but also a little glycerine to keep the chemicals moist.—*The Engineer,* London.

The rescue squad of the New York fire department, operating pulmotors, saved lives at a fire that partially destroyed a five-story tenement on April 26. Twenty persons, overcome by smoke, were revived by the use of pulmotors. The fire started in an apartment in the first story and was carried upward through a dumbwaiter shaft.

Nitroglycerin is a powerful heart stimulant; that is why the fumes cause a severe and prolonged headache when inhaled. The same effect is produced by handling dynamite cartridges with bare hands in hot weather.

COMPRESSED AIR COSTS AND SAVINGS IN RAILROAD SHOPS

BY THOMAS F. CRAWFORD.

Twenty years ago when pneumatic tools were in their infancy the installation of an air compressor did not demand the careful study which is now required, because the wonderful saving in time effected by the substitution of air tools for hand tools overshadowed all other costs. Today, however, instead of a luxury to be found in only the best and most progressive shops compressed air is used in every conceivable plant from the two-stall roundhouse on some isolated branch line to the 40-pit main shop at division headquarters.

RAPID COMPRESSED AIR DEVELOPMENT.

A careful study of the growth of the compressed air system in the average shop reveals the fact that the original system has been gradually extended by additions, owing to the many and varied uses to which the high pressure air medium has been applied. The original single stage, 200 or 300 cu. ft. compressor has been replaced by a cross-compound machine of 1,500 cu. ft. capacity; and it in turn has now been supplemented by still more modern and economical compressors with capacities ranging from 3,000 to 5,000 cu. ft. of free air per minute. Steel cars have revolutionized shop practice, and to-day the repair tracks are demanding from 500 to 3,000 cu. ft. of air, where 15 years ago all work was done by hand. This phenomenal development in many cases has bewildered the mechanical department to such an extent that, in spite of the best practice in air compressor construction and installation, enormous losses are daily incurred through improper piping and the lack of study devoted to the very important subject of air distribution.

PROVIDE PROPER PIPING.

The false economy of using the old piping as the system is extended is eating up hundreds of dollars every day in the boiler room and on the switchboard. It is a well known fact that the cost of air varies as the pressure varies; in other words it costs more to compress a cubic foot of air to a pressure of 100 lb., than to 90 lb. Consequently any arrangement of piping which will tend to reduce the initial pressure at the compressor will save money. Assume for example that a shop is piped for a certain size compressor and with the increased requirements the management finds it necessary to purchase a machine of double the capacity. Then, as is often the case, owing to the cost of the machine rigid economy is enforced as to further expenditures, with the result that the important question of piping is neglected. The old piping is considered good enough and only the necessary extensions to the car tracks or other important points are made. No engineering study of the subject has been made and the money saved at one end is going up the stack at the other.

This can readily be seen when a few facts concerning compressed air are considered. In the first place loss of pressure due to friction in pipe lines increases very rapidly as the diameter of the pipe decreases. The pressure loss when transmitting 500 cu. ft. of air per minute through 1,000 ft. of 3½-in. pipe amounts to 1.39 lb., with an initial pressure of 100 lb. per sq. in., while if the pipe size is cut down to 3 in. the loss of pressure jumps to 3.08 lb. Globe valves and fittings such as tees and elbows add greatly to the frictional loss and great care should be given to their application. It will, therefore, be seen that it does not require many poor conditions to build up an unnecessary load on the compressor.

Let us consider a compressor with a capacity of 3,000 cu. ft. of free air per minute operating during a 10-hr. day at approximately 100 lb. pressure and assume that by some rearrangement or replacement of piping the frictional transmission load on this machine is reduced 10 lb. What will the saving be? Under ordinary or even good railroad shop operating conditions it will amount to nearly $3 per day which, in a year of 300 days, would be $900. This represents the interest on an investment of from $10,000 to $15,000, which would go a long way in providing new piping and would pay for considerable engineering study.

Another phase of the subject which offers possibilities for considerable saving is the after-cooling and reheating of the air, particularly where the moisture is excessive and the weather conditions such that long exposed lines are greatly affected. This, however, is a refinement and may be left for investigation after the greater faults are corrected. It is

mentioned here simply for the purpose of showing the extent of the field that is awaiting attention.

LEAKAGE.

Pipe and hose leakage presents another source of loss which while appearing small, amounts to many dollars annually in railroad operation. Few master mechanics or shop superintendents realize what a leak signifies in dollars and cents. They know it amounts to something and that it should not exist, but their attention is taken up by things which are of more immediate importance as far as their daily duties are concerned. But when it is realized that for every leak amounting to 1/64 in. in diameter on a 100 lb. pressure line there is a loss of 1.2 cents per day, while for a leak amounting to only 1/16 in. there is the enormous loss of 19.35 cents per day, the subject of leaks assumes some importance. Add up all the leaks from New York to Chicago for instance, on one of our trunk line railroads and it will be found that there is quite a sum of money that is simply vanishing into the air.

In the ordinary railroad shop installation having a capacity of from 1,000 to 5,000 cu. ft. of free air per minute it is fair to assume that it is costing from 2.5 cents to 3 cents per day of 10 hours for every cubic foot of air per minute that is compressed, while in smaller plants where single stage compressors and other old types of machines are used, the cost may be much higher. This is particularly true in roundhouses and small shops using tubular boilers without feed water heaters. With these costs as a basis, another field of economy still greater than those already considered becomes evident. It is the operation and care of pneumatic tools.

PNEUMATIC TOOLS.

Even ten years ago little attention was given to this important subject, and if the tools were lucky enough to get any attention it was probably from some handy man passing out drills and taps from the tool room window. The continuous and almost universal use of pneumatic tools today brings up the question not only of repairs, but of economy of operation Instead of waiting until a motor or hammer is broken down before tagging it for the tool room it should be periodically inspected and repaired, and there should be kept a systematic record of the condition of each tool as well as the cost of its upkeep.

The air consumption of each tool should be studied. No up-to-date shop can afford to keep antiquated tools of obsolete design operating on its floor when it is realized that the cost of air is so great. Even the most modern four-piston air motor consumes from 50 to 60 cu. ft. of air per minute, and when it is considered that through wear or lack of attention it is often consuming 70 or 80 cu. ft., a loss in actual dollars and cents is evident, which will, many times over, pay for the repair parts and labor necessary to place the tool in first class operating condition, or even purchase a new one to replace it.

PNEUMATIC TOOL POWER CONSUMPTION.

In order to emphasize the importance of maintenance, attention is called to the fact that on a full load basis for equal periods the cost of the compressed air required to operate an ordinary 35-lb. pneumatic drill used for such work as staybolt tapping, etc., is from two and one-half to three times as great as the cost of electricity to drive an 18-in. engine lathe.

The standard four-piston type air motor has a crank speed varying from 2,000 to 2,500 revolutions per minute, but as this is geared down at the spindle to a speed suitable for the class of work on which it is to be used the casual observer does not realize the amount of action taking place inside the metal casing. However, it is readily seen that with these little air pistons operating at such high speeds it does not require a great amount of false adjustment or wear to soon result in a large increase in air consumption. With the actual cost of air known, and knowing the cost of the various repair parts, such as pistons, bushings, valves, etc., it is an easy matter to determine the economic high and low limits for every tool and to establish a system by which repairs are made on a basis of air consumption tests rather than under present practice.

The apparatus necessary for testing air consumption and power developed, covering both pneumatic motors and hammers is inexpensive and can be operated if desired by a second or third year apprentice. Data can be kept in such shape that every tool will have its record on file covering both the tests made and the parts replaced. With such a system in operation, if an air motor, the card record

of which shows a normal air consumption of 50 cu. ft. per minute, is sent in for test and is found to have a consumption of 60 cu. ft. per minute, on a basis of three cents per day for each cubic foot per minute, it is wasting 30 cents per day, or $9 per month of 30 days. It will not require much calculating to show that regardless of the service which this tool may be giving it should go to the repair bench.

The same idea applies to the various types of hammers, all of which are at times eating up many times their worth when to outward appearances they are in first class condition. With a hammer, however, the waste is not so great, as it is held in the hand in such a manner that the operator becomes extremely sensitive to its operation and can often tell from "the feel" that it is taking too much air. However, the average shopman has never had impressed upon him the great cost of compressed air and his education in the matter by the methods now utilized in safety promotion work would undoubtedly result in eliminating many wastes.—*Railway Age Gazette.*

TESTING A REFRIGERATING SYSTEM WITH AIR

It is customary to test a refrigerating system with air pressure before charging with ammonia. This should be carefully done by experienced men to avoid an explosion by the ignition of the vapor from the lubricating oil, caused by the heat of compression. A thin coating of lard oil should first be applied by hand to the walls of the compressor cylinders and the compressor allowed to run until the pressure reaches 100 lb. or more. It should then be stopped long enough to cool down, then started up again and operated until forty or fifty pounds of additional pressure is obtained, then stopped again. When sufficiently cooled it should once more be started, but at reduced speed, and stopped whenever the discharge pipe becomes hot enough to be uncomfortable to the hand. If these precautions are taken there is little chance of an explosion from internal causes during the test. The men should be kept away from the apparatus as much as possible, however, as there is always a possibility that an accident may occur through the failure of an imperfect joint or from unforeseen weakness in some other part.

The above cautionary advice we reprint from a recent issue of *Power*. When an ammonia compressor is operated with air, and without the precautions here suggested, almost ideal conditions are provided for an explosion, not a mere pressure explosion but one resulting from the ignition of an explosive mixture of air and volatilized hydrocarbon, such as occurs at every driving strike of an automobile engine. The right proportions of oil-gas and air are likely to occur and a temperature may be reached high enough to cause spontaneous ignition.

Such an explosion occurred a few years ago in a large brewery on Third Avenue, N. Y. The piping, about 6 in. and very heavy, was shattered for a hundred feet or more and one or two men, if our recollection is correct, were killed.

AMMONIA EXPLOSIONS IN REFRIGERATING PLANTS

In the preceding article attention is called to the danger of using air for testing purposes in a compressor normally designed and installed for ammonia compression. In the article referred to it is assumed that the danger of explosion comes from the formation of explosive mixtures of air with some volatilized constituents of the lubricating oil; that is, that the presence of vaporized oil in the cylinder and pipes provides the real opportunity and provocation of the explosion.

It would seem, however, from investigations recently reported in a German publication that it may be the ammonia and not the oil that is really the cause. The writer refers to a case of an explosion in a German refrigerating plant, which was ascribed to the decomposition of ammonia in the compressor cylinder and the penetration of the gases into the engine room. This case led to the investigation by the Institute of Physical Chemistry and Electro-chemistry of the Technical High School at Karlsruhe, by S. Schlumberger and W. Piotrowski, who introduced into a bell-shaped glass vessel, 110 mm. (4.33 in.) in diameter, mixtures of ammonia and air in various proportions and ignited them by an electric spark. It was found that a mixture of air with from 16.5 to 26.8 per cent. by volume of ammonia violently exploded in the glass vessel, but that with the ammonia content above or below these limits, no explosion took place. Comparative tests with a tube-shaped vessel have given a slower combustion, due probably to the cooling action of the walls, the region of ex-

plosibility being limited to from 19 to 25 per cent. by volume.

Refrigerating engineers are, however, interested principally in the question whether conditions such as have been shown by this experiment, and which produce explosibility of ammonia and air mixtures, can actually occur in practice. It is hardly likely that under ordinary conditions, 16 to 20 per cent. by volume of ammonia can mix with the air, but that may, of course, occur in exceptional cases, for example, when a defect develops in the operation of the machinery, a rupture of a pipe occurs, or something like that. In the case referred to above, a branch pipe broke and allowed ammonia to flow out. The fireman, who was burned about the face and hands, claims that he heard an explosion and saw a flame. As there was a gas burner in the engine room, the assumption naturally was that an explosive mixture of ammonia and air took fire from the open flame.

However, the author doubts this, because the conditions under which the actual explosion occurred did not coincide with the conditions which were present when the tests were carried out. In the latter case, ignition was caused by an electric spark, and, because of the shape of the vessel, propagated with considerable velocity. It is by no means proved that an ignition could likewise occur from an open gas flame and that the combustion in free air would occur in the same manner as in a closed experimental bomb. As a matter of fact, the author doubts that there was any explosion at all in this case, in the sense of a sudden combustion of a mixture of gases, and he supports his contention by reference to another accident where ignition of ammonia by a gas flame appears to be fairly well established. According to a report of the German Slaughterhouse Paper (*Deutsche Schlacht- und Viehhofzeitung*, November 15, 1914, p. 574), in November, 1914, there occurred in the engine and boiler room of the Municipal Slaughterhouse, at Elbing, a fire due to a rupture on a compressor and ignition of the escaping ammonia by an open gas lamp. It appears that in this case a screw on the compressor piston worked loose and fell between the piston and cylinder cover so that during the return stroke of the piston the cover was fractured. No explosion occurred, but there was a strong fire, which destroyed the roof of the house.

Mr. A. Behr, in a report to the Sixteenth Annual Meeting of the Association of German Inspection Engineers (Verhandlungen der 16. Hauptversammlung des Vereins Deutscher Revisions-Ingenieure), read a paper on the "Decomposition of Ammonia in Ice Machines," where he mentions a grave accident in the brewery of the Hildesheim Brewery Comwas started with the exit valve in the pressure piping closed. As a result, the cylinder was pany, in which case an ammonia compressor blown up by the increasing pressure. Immediately thereafter, the entire engine room, which was lighted by gas, was enveloped in a sheet of flame. In another case, in a Berlin brewery, rapid ignition took place when a fire was brought near an open ammonia compressor. According to the opinion of Mr. Behr this accident was due not to the combustion of ammonia and air mixture, but to the ignition of hydrogen which formed in the engine through the decomposition of ammonia, which decomposition, in its turn, was due to rise of pressure and temperature of ammonia caused by starting the compressor with a closed pressure valve.

That this decomposition does take place was shown by the experiments of Doctor Mohr, who has found in three instances a high content of free hydrogen and nitrogen in experimental compressors. For practical purposes it would be desirable to carry out a theoretical and experimental investigation which would show whether decomposition of ammonia actually takes place, and if so, how it can be prevented.

KEROSENE AS A FIRE EXTINGUISHER

Fire in bales of cotton at Calexico, California, was recently extinguished by kerosene. While this may seem parodoxical the explanation is simple. Cotton in the baling process is subjected to great pressure. Water can penetrate the bale only an inch or so while kerosene will go to the centre. Fire in the bale does not blaze, simply smolders and slowly cuts its way. At the comparatively low temperature at which cotton burns, and where there is no flame and no air, kerosene does not ignite but instead extinguishes the fire in the cotton. After the fire is put out the bands are removed from the bale, the burned portions are pulled out, and after the cotton has been aired for a few days all trace of the kerosene disappears.

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EVERYTHING PNEUMATIC

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DEATH OF DR. HOLMES

Dr. Joseph Austin Holmes, Director of the Bureau of Mines since its organization under is present form in 1910, died of tuberculosis in Denver, July 12, fifty-five years old, thus by the irony of fate, succumbing to the cruel type of disease against which in the Bureau of Mines his efforts had been so constantly and strenuously employed.

Dr. Holmes was born in Laurens, S. C., was educated in local schools and at Chapel Hill, N. C., and graduated from Cornell in 1880. In the following year—his 22nd—he was appointed professor of geology and natural history at the University of North Carolina, remaining in that position for 10 years, and continuing to lecture there several years later. In 1891 he was appointed state geologist of North Carolina, devoting his time for three years to that work, and taking an active part in the preparation of the geological exhibit at the Buffalo Exposition in 1901, which naturally pointed to his selection as head of the Department of Mines and Metallurgy at the St. Louis Exposition in 1904.

In this year his first active work for the government began when he was placed in charge of important fuel tests. In 1905 the director of the United States Geological Survey extended his work to cover mine explosions and other phases of mine work. In 1907 he was made chief of the technologic branch of the Geological Survey, holding that position until the Bureau of Mines was formally established by act of Congress in 1910.

There were several qualified candidates considered for the position of head of the new bureau, but when Dr. Holmes was finally appointed universal approbation greeted him, and the record of the bureau under his direction and stimulus has surpassed all expectation.

The following is the editorial tribute of the *Engineering and Mining Journal*:

The Bureau of Mines became his child. He practically created it, organized it and laid out its course. There is scarcely anything in it whereof the inception is not owed to him. He was ambitious for it and sometimes was criticized for the vaulting character of his ambition, although all recognized that there was never in his mind a thought of personal aggrandizement, but only and always of the

prestige and public usefulness of his institution. For it he worked every hour of the day except when sleeping, traveling thousands of miles annually, enduring the hardships of railway tedium, poor food and miserable hotels, and holding intercourse with thousands of persons. The ability to get on well with people was one of his happy faculties, as also was his art of surrounding himself with able and loyal assistants. He was never willing, however, to relieve himself of arduous duties by delegating them to his assistants. Their function in his mind, was solely to enable his bureau to do more work, and he devoted himself indefatigably to finding it for them to do. He made the Bureau of Mines a great thing in remarkably few years, but in doing it he killed himself, leaving the mining and metallurgical industries of his country his eternal debtors. His special interest was the promotion of safety in mining. With keen perception he singled out the correction of the disgracefully high mortality in American mining as being the first big work that the Bureau ought to do."

Dr. Holmes received the degree of D.Sc. from the University of Pittsburgh and that of LL.D. from the University of North Carolina. He was a member of the Mining Legislation Commission of Illinois, National Conservation Commission, American Institute of Mining Engineers, American Society for Testing Materials, the Academies of Science of St. Louis and North Carolina, American Society of Mechanical Engineers, the Cosmos Club of Washington, the Engineers Club of New York, and was a fellow of the Geological Society of America.

COMPRESSED AIR IN THE SMITHY

The article 'Electrifying the Forge Shop" in the July issue of COMPRESSED AIR MAGAZINE reminds the writer of similar work that was done in the Argentine Republic in 1905, in the new workshops of the Buenos Aires Western Railway Co. When this Company built their new shops they made liberal allowance for the use of compressed air all through the different departments, and also contemplated working the steam hammers in the smith shop by compressed air; but as this was a new venture at that time they were not sure whether it would be a sucess. However, all precautions were taken; large receivers were hung from the roof trusses close to the hammers, and Ingersoll reheaters were provided so as to economize air as much as possible.

This being an untried experiment it was not known whether the air compressing plant would prove sufficient, as a very complete equipment of pneumatic tools had been provided, and the foundry was equipped with molding machines and sand sifters. There were in the Power House two JC compressors with two stage air cylinders 16¼" & 10¼" by 10" driven by 60 H. P. electric motors. The Smith shop had one large steam hammer and two small ones and steam boilers were provided in case their operation by air was not a success. The hammers were run by steam for some time, as the air receivers and piping were not ready, but after being tried out by air their operation was found to be thoroughly satisfactory, and the air compressing plant ample to do the work, together with driving all the pneumatic tools and molding machines in the foundry.

It would be quite impossible to give any idea of the comparative cost of operation by steam and by air, as their work was so intermittent: but it was considered that operation by air was most satisfactory. To run the hammers by steam required a large boiler to be kept constantly under steam, which consumed about a ton of coal a day, costing $10, besides the wages of a fireman and the smoke nuisance. We could not arrive at the amount of extra air required owing to the impossibility of isolating the hammers from the remainder of the pneumatic tools and operating them separately by a compressor; but it seemed to every one, that, not only was it much cheaper to drive them by air, but that their operation was in every way more satisfactory. The hammers worked quicker, were free from condensation, there was no dripping water, nor hot parts to inconvenience and burn the workmen.

J. P. STONE,
104 Madison Ave., N. Y. City.

The chemists of the United States Bureau of Mines have discovered a process whereby radium can be produced at one-third its present cost; or at a price of $40,000 per gram ($1,134,000 per oz., Avoirdupois) instead of $120,000.

EXPLOSIONS IN AIR LIQUEFACTION PLANTS*

There have been several disastrous explosions in plants manufacturing oxygen and nitrogen from liquid air. As a rule, it is quite possible to separate oxygen and nitrogen by fractional distillation in the so-called countercurrent apparatus, but it appears, however, that these apparatus are sometimes subject to highly dangerous occurrences.

The pipes of the column apparatus in which the oxygen is separated from the liquid air have to be thawed out at night because of accumulation of ice. This thawing out process is usually carried out with warm water and, in the meanwhile, the operation of the plant is interrupted. In one case, the attendant was busy thawing out the pipes while a laborer was removing the insulating cork. The foreman had most strictly prohibited the use of a torch, but notwithstanding that the attendant did use one, as he was seen carrying the torch inside. Immediately thereafter, there occurred an explosion which threw aside heavy iron beams, blew up the roof, killed the attendant and did a lot of other damage. The explosion was followed by a fire. It seems reasonable to believe that the attendant approached with his torch too close to the insulating cork of the column apparatus and in this way ignited the mass. Whether the explosion was due directly to the explosive combustion of the cork or was accompanied by the explosion of illuminating gas has not been established. Tests have shown, however, that the extremely porous cork used in this kind of apparatus accumulates in a very short time such large amounts of oxygen in its pores that it becomes highly explosive.

Another explosion which likewise occurred in an air liquefying plant is also of great interest. It occurred in a plant manufacturing from liquid air pure nitrogen to be used for the production of calcium nitrate. In this case the separation apparatus exploded, mortally wounding the foreman. In this apparatus, the air was compressed to four atmospheres, and was thence led to the liquefaction system where it was allowed to trickle in a column apparatus 3 m. high. The nitrogen evaporated while the oxygen collected in two vessels connected by an overflow. In order to free the nitrogen from the last traces of oxygen, a part of the nitrogen compressed to 100 atmospheres flowed in a thin spiral through the countercurrent helix and through the collector filled with liquid air or oxygen, whence it flowed freely into the upper part of the column. While this was done, the last traces of the oxygen contained in the nitrogen were liquified and flowed down into the collector, and this, as well as the column, was equipped with a safety valve which prevented the pressure therein from exceeding 0.5 atmospheres.

The explosion, which caused a large amount of damage, was not due to excessive pressure, as the presence of a safety valve protected it from that. Two separate detonations appear to have been heard and it seems that the collector was the first to be destroyed, whereupon the oxygen flowing out produced an explosive combustion of the insulating silk. After the first detonation, the foreman rushed to the apparatus but was thrown back by the second explosion, and hurled against a compressor. Previous to that another explosion of a similar nature had taken place, which was ascribed to the fact that in some manner or other the air taken in contained traces of acetylene and that copper acetylide, which is highly explosive, was formed. It does not appear likely, however, that copper acetylide would decompose explosively at a temperature as low as that of boiling liquid air.

The author describes a third explosion which destroyed an enitre factory and caused a heavy loss of life. The persons who were in the factory saw a bluish flame, similar to that of lightning, start from the ground. Then a big gray cloud of dust was seen and finally a tremendous detonation was heard, after which the building practically collapsed. Some of the bodies recovered from the ruins were found to be terribly mutilated. The separation apparatus had entirely disappeared and there was an immense hole in the wall near which it stood. From the testimony of the workmen who were in the factory just previous to the explosion, the following is what apparently occurred: The chief engineer and his assistant had started the plant in the morning and it appeared to be working all right. They forgot, however, to blow off the dew which accumulated in the apparatus after it had been standing idle over Sunday and had

*A. S. M. E. Journal abstract from the German.

become somewhat warm. Notwithstanding the most careful cleansing of the air previous to its admission into the liquefaction system, a certain amount of water settled down as ice in the separation apparatus; this had to be melted and removed from time to time. A couple of hours after the plant was started, the foreman inspected it and found everything in order, but apparently the apparatus had simply frozen. When the engineer, who was working the apparatus alone, did not know what to do, he went to the superintendent and was ordered by him to thaw out the apparatus, the superintendent then withdrawing to take care of his clerical work. The engineer, however, notwithstanding strict orders not to bring any fire or hot objects near the apparatus, heated, by a torch, up to red heat, a large wrench used for tightening the stuffing boxes of the expansion valves, and put it into the expansion valve when the insulation of the apparatus apparently caught fire.

Some other cases of explosions in air liquefaction plants are likewise described. From all these, it appears that the causes of explosions may be divided into two classes—one, which is obvious, produced by the prohibited use of an open flame, and the other, less obvious, due probably to some sort of chemical action or freezing.

The author calls attention to the following facts as serving as possible explanations of explosions of the second class. Essentially, air consists of a chemical mixture of oxygen and nitrogen, in addition to which there are present in it, water vapor, carbon dioxide, complex gases and the so-called noble gases, such as argon, metargon, helium, xenon, neon, and krypton. The essential properties of these noble gases are that they apparently do not enter into any chemical combination either among themselves or with other gases. The most important of them is argon, of which there is present in the air approximately 0.935 per cent by volume. It liquefies at — 186 deg. cent.; oxygen at — 184 deg. cent. and nitrogen at — 194 deg. cent. In apparatus where nitrogen is produced and where, therefore, a very low temperature has to be maintained, it is quite possible that argon settles down in the pipes, forms an ice-like mass and in this way bottles up the air passages, thus raising the compression of the gas up to the point where it explodes the apparatus.

It is also possible that argon brings about explosions in another manner. Essentially, the noble gases have not a molecular, but an atomic structure; that is, they consist of single atoms. It is, however, possible that this structural property changes at very low temperatures, and in the argon ice the atoms of the gas combine into a complex gas, which dissociates explosively when the temperature rises. Similar explosive dissociations may also take place in the case of peroxide of hydrogen and ozone.

Another source of danger which may cause explosions is the presence of combustible substances in the liquefied air, due, for example, to the penetration of oil from the compressors or perhaps of products of decomposition of lubricating oil formed in the compressors under the influence of the heat of compression. It is also well to bear in mind that in the atmospheric air there are present small amounts of hydrogen and methane, and it is quite possible that if both gases are present in equal amounts they may, after a certain length of time, appear in quite substantial quantities in liquefied air. Considering that air liquefaction plants have usually an output of 400 cu. m. (14,125 cu. ft.) per hour, or 4,000 cu. m. per working day of 10 hr., and considering further that there may quite easily be 0.05 per mil of methane, this would be equivalent to 200 l. (52.8 gallons) of liquid methane, an amount sufficient to create a tremendous explosion in the presence of liquid air or oxygen.

There is one more fact which has to be borne in mind. Ozone may convert hydrocarbons into highly explosive compounds—so-called ozonides or peroxides. Harries produced such explosive compounds even from hydrocarbons having annular formation, such as benzole and toluol, and from other derivatives of methane. Saturated hydrocarbons, such as methane, produce explosive substances of the peroxide type and can be converted into formaldehyde and formic acid. From methane derivatives are also produced ozonides proper, which in most cases are highly explosive, and in the presence of water dissociate into aldehydes and peroxide of hydrogen. Unsaturated ketons, aldehydes and single-base acids of fats combine with four atoms of oxygen thereby also forming explosive compounds. It appears, therefore, that unless ex-

treme care is exercised, there are numerous sources of danger in the production of liquid air and its component gases.

GAS FOR INDUSTRIAL PURPOSES

The use of gas for industrial purposes is rapidly increasing, particularly where a supply of a cheap by-product gas is available. But coal gas supplied by town companies is also progressing in the same direction, and is making up by its convenience, and by a number of smaller economies which are possible with its use for its higher cost as compared with coke or coal. In order to let London manufacturers see what can be done and to encourage the consumption of gas in its own area, the Gas Light and Coke Company has opened a large demonstration building in its depot at 146, Goswell-road. At one end of this building is an engine-house, where a small gas engine drives a compressor, raising gas to what is known as high pressure—about 100 in. of water—whilst a fan provides air also at "high pressure." In this room are also to be found meters for measuring the gas supplied at and above atmospheric pressure. The different pipes leading from the engine-room are painted in distinctive colours according as they convey gas at atmospheric or at high pressure, or high-pressure air. In the body of the building is arranged a representative collection of gas-heated industrial furnaces and appliances of all kinds; there are furnaces for heating and tempering tools, furnaces for melting metals of various kinds either for foundries or printing houses, etc., furnaces for enameling, a salt bath furnace, muffles of various forms and sizes, burners for sugar boiling, and burners for heating soldering irons, blow pipes, etc. This very representative exhibition has been provided by several firms. Some of the burners use both gas and air at atmospheric pressure; others use both at high pressures, and others one or the other only at high pressure.—*The Engineer*, London.

WELLS MORE THAN A MILE DEEP

The deepest well in the world is in Upper Silesia, in the German Empire. It is a diamond-drill hole in a coal field and is 7,350 feet deep. A well in the United States which may go deeper, according to the United States Geological Survey, is 4 miles northwest of McDonald, Pa., and about 15 miles west of Pittsburgh. This well, which is being sunk to the Medino sandstone—a bed that elsewhere contains oil and gas—is now 7,174 feet deep. Some gas and oil were struck in the upper part of the well. Between the depths of 6,830 and 7,100 feet rocks bearing rock salt and salt water were encountered. These are regarded as of Salina age, the same as those carrying rock salt in western New York. The temperature in this well at the depth of 6,775 feet, as recently determined with great accuracy, is 145.8 degrees F.

At Derrick City, McKean County, Pa., near Bradford, there is a well 5,820 feet deep, which is probably the second deepest well in the United States. Another deep well is on Slaughter Creek, Kanawha county, W. Va.; it is 5,595 feet deep. It penetrated a sandstone at 5,030 to 5,050 feet, and from this depth to the bottom, a distance of 545 feet, the well is in limestone. Near West Elizabeth, Pa., there is another well 5,575 feet beneath the surface, penetrating into a blackshale. Another deep well is being drilled at Gaines, Pa. This has already reached a depth of 5,500 feet. Deep-well drillers in this country of course employ the most improved and effective rigs, but one of the most remarkable of wells, reaching a depth of 3,600 feet, was drilled for petroleum in western China by means of such crude appliances as a cable made of twisted strands of rattan.

GRANITE NOT THE OLDEST OF ROCKS

It used to be thought that granite was the oldest of all rocks and that it formed the globe's first crust. Now, however, geologists believe that granite may be of any age or epoch. The granites found in Germany and the Vosges Mountains, of France, date from one period of the world's history; those found in the British Isles, from an entirely different period; and those found in the United States from still other periods.

Enormous pressure, combined with heat and water, must have been necessary to produce granite. Some scientists declare that the granites in the Highlands of Scotland must have been formed when 60,000 feet of overlying rocks were piled above them, and that those of Cornwall required 40,000 feet of rock pressure.

NOTES

The pneumatic method of placing concrete was used successfully for conveying the mix 2805 ft. through a 6-in. pipe on the Mile Rock tunnel work at San Francisco. The compressor capacity installed was 1,200 cu. ft. per minute, and the receiver pressure was kept at about 115 lb. per square inch. This is regarded as a record for long-distance work of this character.

The British height flying record, which stood at 14,500 ft., was beaten at the Hendon Aerodrome on Sunday last, June 6th, when Mr. Hawker, on a new type Sopwith biplane, reached an altitude of over 20,000 ft., nearly four miles. Although it was a perfectly clear day, the pilot actually disappeared from sight and could only be discerned through powerful glasses.

Hydrogen was discovered or isolated in 1766 by Cavendish, an eccentric English chemist, who called it "inflammable air," but the French chemist, Lavoisier, named it hydrogen, meaning "water former." Nitrogen was also identified as a constituent of air at about the same date as oxygen and hydrogen (1766 to 1774) and named nitrogen by Chaptal, because of its existence in niter.

An exhibit at the San Francisco Exposition, illustrates the variety of uses which science has found for soft coal. An enormous block of coal is shown surrounded by its products. The first "generation" consists of ammonia, illuminating gas, crude benzol, coal tar, and coke. The derivatives of each of these substances are in turn grouped around it. Coal tar, for instance, is the parent of Tarvia and other bituminous road binders, numerous ready-roofings, creosote oil, etc.

Do not fool with compressed air, as it is dangerous if handled carelessly. Never blow it on anyone, as it may enter his body and injure or kill him.—*American Machinist.*

This is nonsense, neighbor. They blow compressed air onto you in the barber shop. They can't blow it into you any more than they can blow steam into you, and air won't scald. Nothing is safe if used without common sense, and with common sense nothing is safer than compressed air.

Plans for the ventilation of the new subway lines in New York are to be considered by a board of engineers. The present plan is to ventilate by means of open gratings on the sidewalks, which plan is opposed by the merchants on the ground that the gratings are avoided by pedestrians and they thus will look less into the store windows, which is more or less true. Single tubes with the trains acting as pistons would secure a constant change of air.

The sixteen inch gun built at Watervliet Arsenal more than ten years ago, the only gun of this calibre built by the United States, has been taken to Panama Canal where it will have a disappearing mounting costing much more than the gun, and its effective life may be expected to be ended when about 100 shots have been fired. A number of fourteen inch guns will be placed at Panama, these costing $45,000 each and their carriages $85,000. The cost of a powder charge for one of these is $175 and of the projectile about $500.

Tests have shown that moist acetylene, as generated, attacked zinc, lead, brass and nickel to a slight extent; iron was affected at about six to seven times the rate; phosphor bronze about twice as much as iron; but copper suffered more than any other metal tested. Copper was quickly changed into a soft, porous black mass. Tin, aluminium, bronze, German silver, and solder were practically unaffected. Thus it would appear that copper and brass or other copper alloys should not be used as piping for acetylene gas supplies, and that iron should be well tinned rather than galvanized or nickel-plated.

The principal use for tungsten is in the manufacture of high-speed steel, which holds its temper at much higher temperatures than does carbon steel. There are many applications for ductile tungsten; the ductile metal is practically insoluble in all of the common acids, its melting-point is higher than that of any other metal, its tensile strength exceeds that of iron and nickel, it is paramagnetic, it can be drawn down to smaller sizes than any other metal, while its specific gravity is 70 per cent. higher than that of lead. One important use of ductile tungsten is that large quantities

of drawn wire are produced, both flexible and strong, for the manufacture of incandescent lamps.

Some arbitrarily coined trade words, such as kodak, find a permanent place in the dictionary. Another respectable class of trade words, not one of which, so far as we know, has as yet reached the dictionary, are those formed of the initials of a manufacturing company with the syllable "co" added, a good example of which is the "Mesco" of the Manhattan Electrical Supply Co.; but perhaps the simplest of all is the "Irco" of the Ingersoll-Rand Company. Kodak serves as both a noun and a verb; but Irco is also an adjective descriptive of a superior metal for rock drills and mining apparatus.

The first American exposition of chemical industries will be held at Grand Central Palace, New York City, during the week beginning Sept. 20, 1915. It is to be managed by C. F. Roth and A. Nagelvoort, assisted by an advisory committee of nine eminent chemical engineers. It is expected to include coal, wood and petroleum products, metals, minerals, water and sewage purification, air and gas processes, glass and ceramics, oils, varnishes, plastics, rubber, leather, glue, etc. Working exhibits will be shown. Inquiries should be directed to the National Exposition of Chemical Industries, 46th St. and Lexington Ave., New York City.

The use of poisonous gas by the Germans in the French trenches suggests some great possibilities for the defensive as well as the offensive. The *Bystander,* a British publication, says that the device has surely come to stay though properly enough denounced as a violation of the present laws of warfare. No Hague Conventions are likely to abolish it—if there are any more such ridiculous things as Hague Conventions. One foresees that instead of fortresses henceforward each country will line its frontier with gas jets, which, being invisible and their works subterranean, will be indestructible. The knowledge that his landing on these shores, if effected at all, will be greeted by blasts of his own poison-gas, made as noxious as chemistry can make it, will digress the enemy's ardor somewhat Our contemporary has forgotten that it will be quite possible to supply masks or helmets connected to reservoirs containing air either compressed or liquefied.

LATEST U. S. PATENTS

Full specifications and drawings of any patent may be obtained by sending five cents (not stamps) to the Commissioner of Patents, Washington, D. C.

The following official notice from the Commissioner of Patents will sufficiently explain any break in our regular weekly report of patents issued.

Department of the Interior,
United States Patent Office,
Washington, D. C., June 10, 1915.

On account of the unusually large number of patents issued during the current fiscal year the regular appropriation of $440,000 for printing specifications and the Official Gazette and a supplemental appropriation of $125,000 have been nearly exhausted. It will not be possible to issue the Gazette for June 15, 22 and 29 on these dates. These issues will be sent out as early in July as the publication thereof can be brought about. Owing to the resulting congestion there probably will be some delay in the issues of the Gazette for July until conditions in the office of the Public Printer again become normal. There will be no delay in the issuance of patents, designs, or trade-marks.

THOMAS EWING,
Commissioner of Patents.

JUNE 1.

1,141,109. ELECTROPNEUMATIC BRAKE FOR RAILWAY-CARS. James S. Doyle, New York, N. Y.

1,141,114. CONTROLLER FOR FLUID-PRESSURE-ACTUATED DEVICES. Clark T. Henderson, Milwaukee, Wis.

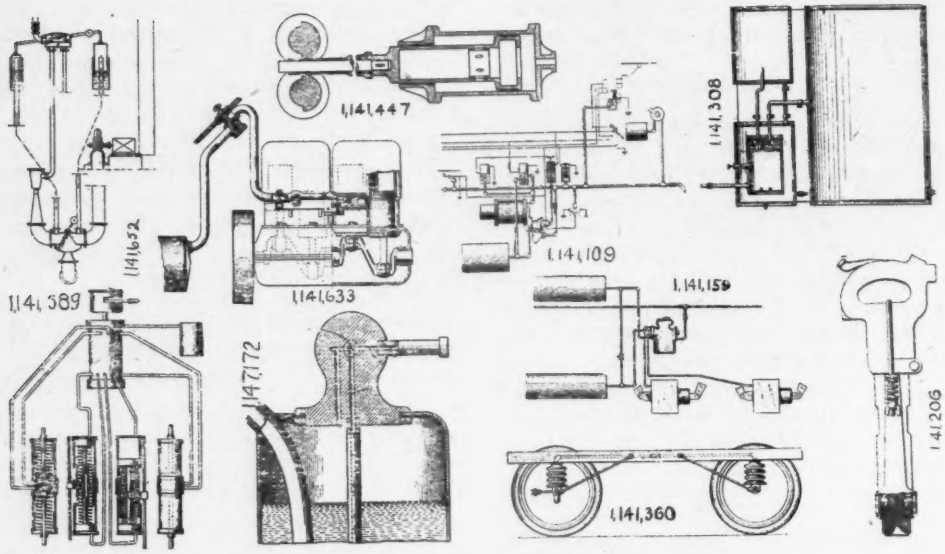
1,141,159. CONTROL-VALVE DEVICE FOR FLUID-PRESSURE BRAKES. Walter V. Turner, Edgewood, Pa.

1,141,206. CLUTCH FOR A PNEUMATIC HAMMER. Samuel Oldham, Philadelphia, Pa.

1,141,236. UNIVERSAL AIR-BLAST. Jacob Diehl, Glenbeulah, Wis.

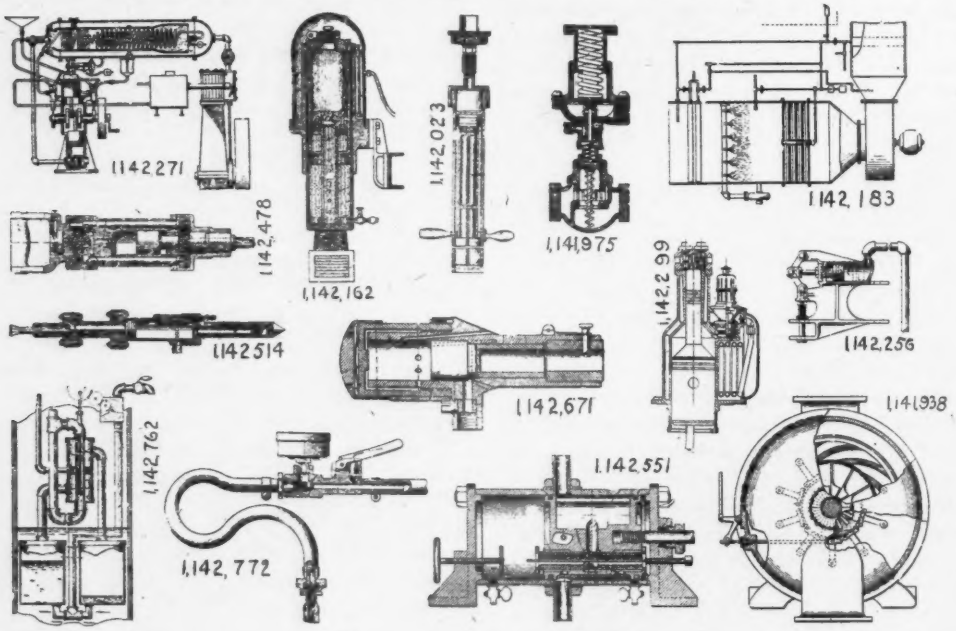
1,141,308. POWER-GENERATOR. George Boltz, Amy, Kans.

The combination with a tank for compressed air, a reservoir for a hydrocarbon fluid, a water tank and a generating chamber arranged spaced apart within the water tank, of a body of asbestos arranged at one end of the generating chamber, a grate member extending transversely of the generating chamber and confining the as-



PNEUMATIC PATENTS JUNE 1.

bestos at the end of such chamber, a valved spray pipe extending through the water tank and into the generating chamber in the front of the grate, said spray pipe having a lateral port therein through which the water in the water tank may pass, said water being admitted to the generating chamber in the form of a spray, a pipe leading from the hydrocarbon reservoir to the asbestos body to supply hydrocarbon fluid thereto, a valved pipe for conducting air under pressure to the reservoir to force the hydrocarbon fluid therefrom into the generating chamber, a valved pipe for conducting air from the compressed air tank to the generating chamber where it is mixed with the hydrocarbon fluid at the asbestos body within the generating chamber, a valved pipe for conducting air to the water tank to force the water into the generating chamber, and a valved pipe for conducting the steam and heated gases generated in the generating chamber to the point of use.



PNEUMATIC PATENTS JUNE 8.

1,141,360. PNEUMATIC CUSHION. HERBERT F. RUDD, Belpre, Kans.

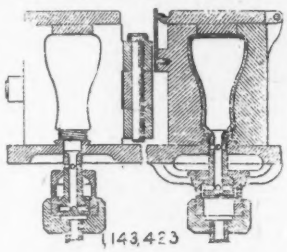
1,141,379. PNEUMATIC ACTION FOR AUTOMATIC PLAYERS. MELVILLE CLARK, Chicago, Ill.

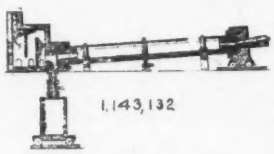
1,141,447. ROLLING-MACHINE. OSCAR DELLWITZ, Tegel, near Berlin, Germany.

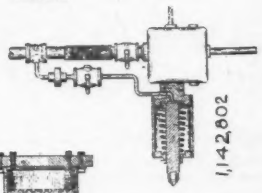
1. In a pilgering mill, the combination comprising a cylinder adapted to be supplied with a compressed fluid, a piston mounted within said cylinder and adapted to leave a hollow space between a portion of said piston and the forward end of the cylinder, said piston having means of communication with the hollow space and being adapted in its movement to close said means of communication so as to form a cushion, and a mandrel mounted in said piston.

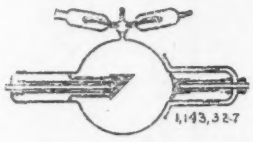
1,141,589. FLUID-PRESSURE AUTOMOBILE CONTROL MECHANISM. NICHOLAS TAYLOR, Muskogee, Okla.

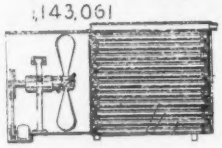
1,141,597. VACUUM-CLEANER. MORRIS S. WRIGHT, Worcester, Mass.

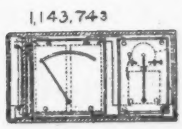


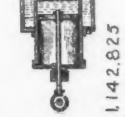


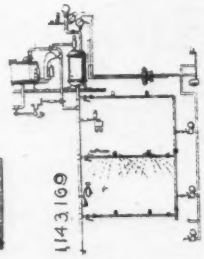


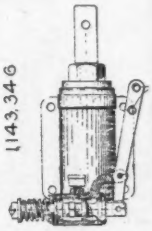


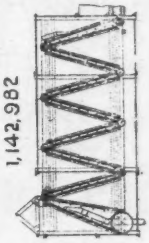


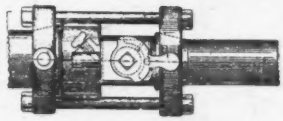


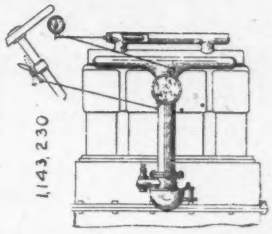












PNEUMATIC PATENTS JUNE 15.

1,141,621. PNEUMATIC SELF-PLAYING MUSICAL INSTRUMENT. LEWIS B. DOMAN, Elbridge, N. Y.

1,141,633. SELF-STARTING INTERNAL-COMBUSTION ENGINE. JOHN ALLEN HEANY, Washington, D. C.

1,141,650. JACK HAMMER-DRILL. SAMUEL OLDHAM, Philadelphia, Pa.

1,141,652. BLOWING SYSTEM FOR FURNACES. HEINRICH POETTER, Dusseldorf, Germany.

1,141,721. ATOMIZER. JAMES G. MASTIN, Chicago, Ill.

JUNE 8.

1,141,938. AIR-REGULATING DEVICE FOR CENTRIFUGAL COMPRESSORS. CLARENCE P. CRISSEY, East Orange, N. J.

1,141,939. AIR-BRAKE FOR MOTOR-CARS. IRVIN CRUM, Selma, Ala.

1,141,948. PRODUCTION OF AMMONIA. FREDRIK W. DE JAHN, New York, N. Y.

The herein described process of producing ammonia, which comprises suitably passing a gaseous mixture containing nitrogen and hydrogen under a pressure less than 100 atmospheres in contact with a heated catalytic agent containing (1) cobalt, (2) sodium and (3) nitrogen.

1,141,975. PNEUMATIC CONTROLLER. JOHN L. OSBORNE, Rochester, N. Y.

1,142,023. SUCTION APPARATUS FOR DENTAL CASTING APPARATUS. EDWARD L. CHOTT, Chicago, Ill.

1,142,162. FLUID-PRESSURE CUSHIONING AND WEIGHING MECHANISM. LUCIEN R. GRUSS, San Francisco, Cal.

1,142,271. METHOD AND MEANS FOR THE GENERATION OF COMPOUND MOTIVE FLUID. BENNETT L. RINEHART, Philadelphia, Pa.

1,142,299. COMPRESSOR. WALTER W. BROWN, Erie, Pa.

1,142,478. PERCUSSIVE TOOL. LEWIS C. BAYLES, Easton, Pa.

1,142,483. METHOD OF HUMIDIFYING AIR. WILLIAM G. R. BRAEMER and SAMUEL C. BLOOM, Camden, N. J.

1,142,514. PULSATOR-DRIVEN PERCUSSIVE TOOL. ARTHUR H. GIBSON, Easton, Pa.

1,142,551. FLUID-PRESSURE MOTOR. GEORGE W. BURNHART, Denver, Colo.

1,142,671. PNEUMATIC TOOL. BENJAMIN M. CARMINA, New York, N. Y.

1,142,762. DEVICE FOR ELEVATING FLUIDS. WILLIAM J. MCGUIRE, Kewanee, Ill.

1,142,772. AIR-GAGE APPLIANCE. CARL E. L. LIPMAN, Beloit, Wis.

JUNE 15.

1,142,802. DRILLING AND BORING MACHINE. JOSEPH L. DIDIER, Salisbury, N. C.

1,142,825. SHOCK-ABSORBER. WILLIAM F. LYONS, Kansas City, Mo.

1,142,827. PROJECTILE FOR AIR VESSELS. RICHARD MACHENRACH, Schlebusch, near Cologne, Germany.

1,142,860. FLUID-PRESSURE BRAKE. WALTER V. TURNER, Edgewood, Pa.

1,142,982. MEANS FOR CLEANING AIR. HARVEY J. RICHARDSON, Chicago, Ill.

1,143,061. DEHUMIDIZER. GLEN O'BRIEN, Manhattan, Kans.

1,143,064. PNEUMATIC TURBINE-GRINDER. CHARLES PERKINS, Bridgewater, Mass.

1,143,132. PROCESS OF FIXING ATMOSPHERIC NITROGEN. SAMUEL PEACOCK, Chicago, Ill.

1. The method of fixing atmospheric nitrogen in fuel fed furnaces, which consists in providing a suitable furnace charge of carbon and an oxid the carbon being in such excess as to preclude the formation of carbon dioxid during the process; and feeding free nitrogen, air and fuel to said furnace and thereby subjecting said charge to a temperature sufficient to fix the said free nitrogen, as well as some of the nitrogen left in said air after the oxygen has been consumed, substantially as described.

1,143,169. FIRE-EXTINGUISHING APPARATUS. EDWARD R. BRODTON, Washington, D. C.

1,143,230. AIR-CONTROLLED DEVICE FOR GAS-ENGINES. WILLIAM A. ROOT, Bennington, Vt.

1,143,677. BLOWPIPE. MILTON E. WINANS, Newark, N. J.

1,143,708. APPARATUS FOR SEPARATING SHEETS FROM A PILE OR STACK. JACOB HEINRICH, Nuremberg, Germany.

1,143,833. VACUUM-CLEANER. WILLIAM H. KELLER, Philadelphia, Pa.

1,143,923. CRUDE-OIL BURNER, EDWARD D. VARNUM, San Diego, Cal.

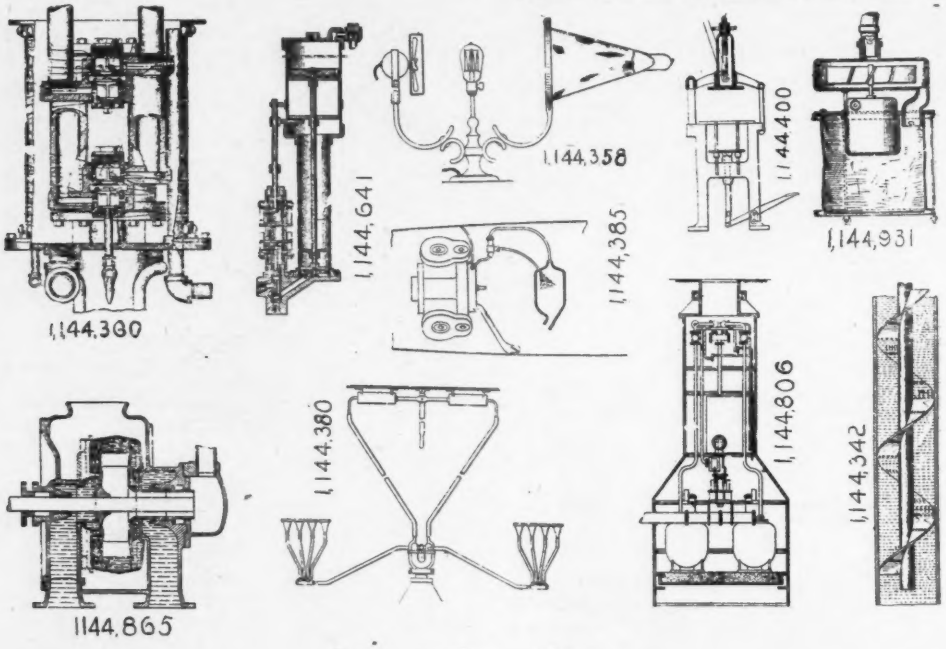
1,143,962. AIR-MOISTENER. CLARENCE B. HAYNES, Camden, N. J.

1,144,203. PNEUMATICALLY - OPERATED WINDOW-CLEANER. FREDERIC WILLIAM HOGG, The Dalles, Oreg.

1,144,297. RIVETING-MACHINE. MANLEY J. CHAPLIN, Seattle, Wash.

JUNE 29.

1,144,342. AIR-LIFT FOR ELEVATING LIQUIDS. BENJAMIN ANDREWS, Houston, Tex.



PNEUMATIC PATENTS JUNE 29.

1,143,327. VACUUM REGULATION. HOMER CLYDE SNOOK, Cynwyd, and EDWIN W. KELLY, Philadelphia, Pa.

1,143,346. PNEUMATIC TRIP. ARCHIE M. BAIRD and HARVEY D. PALMER, Topeka, Kans.

1,143,423. GLASS-MOLDING APPARATUS. FRED C. MESSNER and JOHN WILLIAM LAMPARTER, Moundsville, W. Va.

1,143,473-4. CONTRIVANCE FOR AUTOMATICALLY DETECTING THE PRESENCE OF CERTAIN GASES AND VAPORS. ALFRED WILLIAMS and LEO DAFT WILLIAMS, London, England.

1. An apparatus for detecting, by electrical manifestations, the presence of combustible gases in the atmosphere, comprising a casing having an open and a sealed compartment, a pair of thermo-electric elements in the open compartment, a catalytic element in one of said thermo-electric elements, and a circuit for said thermo-electric elements, a voltmeter and a relay inserted in said circuit and situated in the sealed compartment, and means for maintaining said thermo-electric elements at an even heat.

1,143,533-4. PRESSURE-ACTUATED TOOL. GEORGE H. GILMAN, Claremont, N. H.

JUNE 22.

1,143,620. TRIPLE-VALVE-TESTING APPARATUS. CLYDE C. FARMER, Chicago, Ill.

1,144,358. INSECT-CAPTURING APPARATUS. KNUT GEORGE GYLLSTROM, Richmond Hill, N. Y.

1,144,360. VALVE MECHANISM FOR GAS-COMPRESSORS. HENRY W. JACOBS and HOWARD H. LANNING, Topeka, Kans.

1,144,380. COW-MILKING MACHINE. ALBERT VICTOR RACKSTRAW, Bedford, Ohio.

1,144,385. DEVICE FOR THE INJECTION OF WATER AT HIGH PRESSURE INTO THE AIR-REHEATERS OF TORPEDO-ENGINES. EUGENE SCHNEIDER, Le Creuzot, France.

1,144,400. HAND MOLDING-MACHINE WITH LIFTING ARRANGEMENT. ANTOINE UTARD, Longeville, France.

1,144,641. COMPRESSOR-PUMP. EDWARD W. COMFORT, Winchester, Mass.

1,144,806. PNEUMATIC EJECTOR. EDWARD CYRIL BOWDEN-SMITH, Brockenhurst, England.

1,144,838. HAND-RAMMER OPERATED BY COMPRESSED AIR. JOHANN FRIEDRICH WILHELM GRIESE, Hamburg, Germany.

1,144,865. ROTARY PUMP, CONDENSER, OR COMPRESSOR. EDMUND SCOTT GUSTAVE REES, Wolverhampton, England.

1,144,931. VACUUM-CLEANER. ARCHER BOOGHER, Roanoke, Va.

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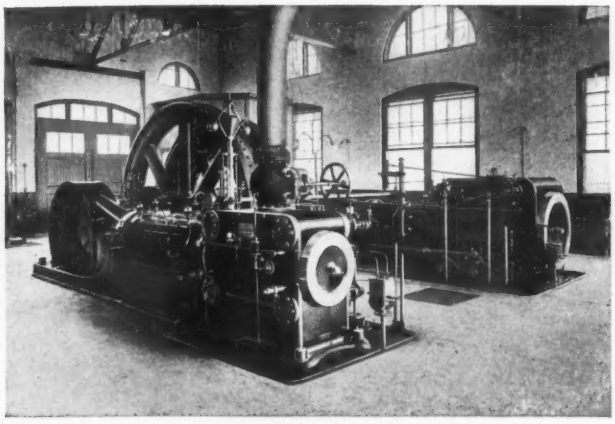

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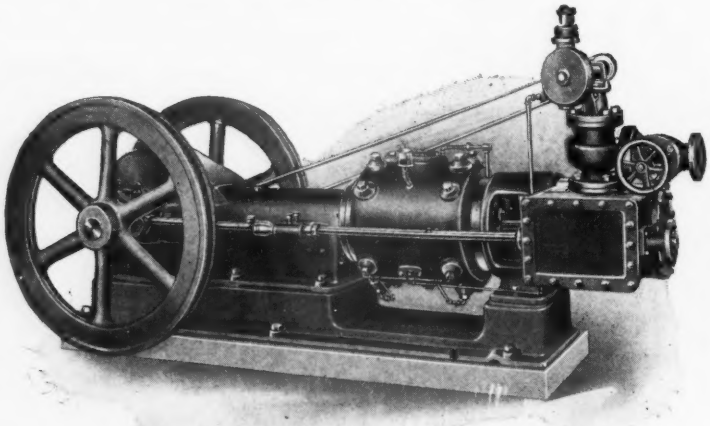

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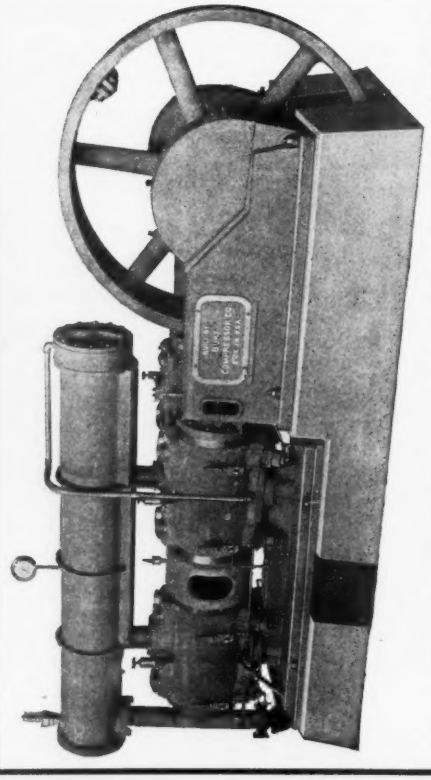

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